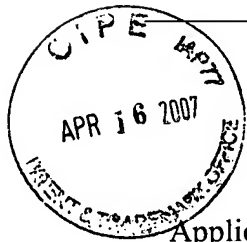


Please Direct All Correspondence to Customer Number **20995****TRANSMITTAL LETTER****APPEAL BRIEF**

Applicant : Satoh et al.  
App. No : 10/759,953  
Filed : January 16, 2004  
For : SEMICONDUCTOR-PROCESSING  
DEVICE PROVIDED WITH A  
REMOTE PLASMA SOURCE FOR  
SELF-CLEANING  
Examiner : Jeffrie Robert Lund  
Art Unit : 1763

**CERTIFICATE OF MAILING**

I hereby certify that this correspondence and all marked attachments are being deposited with the United States Postal Service as first-class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on

April 13, 2007

(Date)

  
Eli A. Loots, Reg. No. 54,715**Mail Stop Appeal Brief - Patents**

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Sir:

Transmitted herewith for filing in the above-identified application are the following enclosures:

- (X) Appeal Brief in 18 pages
- (X) Appendix A in 5 pages.
- (X) Appendix B in 113 pages.
- (X) Appendix C in 1 page.

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Docket No. : ASMJP.055DV1

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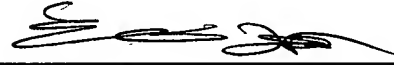
Application No. : 10/759,953

Filing Date : January 16, 2004

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Dated: April 13, 2007



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Eli A. Loots

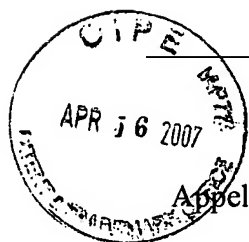
Registration No. 54,715

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Please Direct All Correspondence to Customer Number **20995****APPEAL BRIEF**

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 App. No : 10/759,953  
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Eli A. Loots, Reg. No. 54,715

**Mail Stop Appeal Brief-Patents**

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Dear Sir:

This Appeal Brief relates to an appeal to the Board of Patent Appeals and Interferences of the final rejection set forth in a final Office Action mailed November 16, 2006 and the Advisory Action mailed February 2, 2007 in the above-captioned application.

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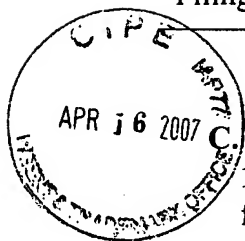
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### **I. REAL PARTY IN INTEREST**

The real party in interest in this appeal is the assignee of this application, ASM JAPAN K.K.

### **II. RELATED APPEALS AND INTERFERENCES**

Appellants are unaware of any related appeals or interferences.

### **III. STATUS OF CLAIMS**

Claims 1-3, 5-10, 14-19, and 45 are currently pending and are the subject of this Appeal; Claims 1 and 9 are the only independent claims. All of these claims are rejected as obvious under a variety of grounds as detailed below. Claims 11-13 have been withdrawn. Claims 4, 7, and 20-44 have been cancelled. The claims are attached hereto as Appendix A.

### **IV. STATUS OF AMENDMENTS**

The claims before the Board appear as they were finally rejected in the Office Action mailed December 16, 2006. No further amendments were made to the claims after the Final Rejection. These pending claims are attached hereto as Appendix A.

### **V. SUMMARY OF CLAIMED SUBJECT MATTER**

The invention relates generally to a CVD device with a remote plasma discharge chamber for cleaning a deposition chamber of the CVD device. More specifically, the invention involves a remote plasma discharge chamber having walls made of an aluminum alloy (*see, e.g.* ¶¶ 0023 and 0024 of the published version of U.S. App. No. 10/759,953, hereinafter the "953 Application". The remote plasma discharge chamber has a RF source of energy associated with it (*see, e.g.*, ¶¶ 0019, 0023, and 0024). Additionally, the invention further involves a specific type of valve positioned in a piping connecting the CVD chamber and the remote plasma discharge chamber. The valve of Claim 1 has an opening that, when fully opened, defines a pressure drop across the valve of less than about 0.25 Torr (¶ 0023). The valve of Claim 9 has an

opening that is sized so that, when the valve is fully opened, the opening is substantially equal in width to an inner surface of the piping, and the valve does not have projections, when fully opened, with respect to the inner surface of the piping (*see, e.g.*, abstract, ¶¶ 0021, 0023, 0026, 0112, FIG. 4A, and FIG. 4B, original Claims 7, 27, and 9). In general, these particular valves minimize recombination of the cleaning gas and allow for faster cleaning rates for the device (¶ 0026). Each of the elements of the independent claims is discussed in more detail below.

Claim 1 recites, with reference to FIGS. 3-5:

A chemical vapor deposition (CVD) device 1 comprising

a deposition reaction chamber 2; (¶¶ 0003 and 0136)

a plasma discharge chamber 13 that is provided remotely from the reaction chamber 2 (abstract, ¶¶ 0009, FIG. 5); wherein the plasma discharge chamber 13 comprises (1) a wall that comprises an aluminum alloy, wherein the wall is exposed to plasma discharge (¶¶ 0023, 0024, 0082), and (2) a radio-frequency (RF) energy source connected to plasma discharge chamber electrodes (¶¶ 0019, 0111, and 0024);

a source 163 of a cleaning gas, wherein the source of the cleaning gas is connected to the plasma discharge chamber 13 (¶ 0152, FIG. 5);

a piping 14 that links the reaction chamber 2 and the remote plasma discharge chamber 13 (abstract, FIG. 3); and

a valve 15 positioned in the piping 14, wherein the valve 15 has an opening 22, 23 that, when fully open, defines a pressure drop across the valve 15 of less than about 0.25 Torr (¶¶ 0023, 0099, FIGs. 4A and 4B),

wherein energy coupled to the remote plasma discharge chamber 13 activates cleaning gas within the plasma discharge chamber 13, and the activated cleaning gas is exposed to the aluminum alloy wall and brought into the inside of the reaction chamber 2 through the piping 14 and changes solid substances adhered to the inside of the reaction chamber 2 as a consequence of film formation, to gaseous substances, thereby cleaning the inside of the reaction chamber 2 (¶¶ 0018, 0082).

Claim 9 recites, with reference to FIGS. 3-5:

A chemical vapor deposition (CVD) device comprising:

a deposition reaction chamber 2; (§§ 0003 and 0136)

a plasma discharge chamber 13 that is provided remotely from the reaction chamber 2 (abstract, § 0009, FIG. 5); wherein the plasma discharge chamber 13 comprises (1) a wall that comprises an aluminum alloy, wherein the wall is exposed to plasma discharge (§§ 0023, 0024, 0082), and (2) a radio-frequency (RF) energy source connected to plasma discharge chamber electrodes (§§ 0019, 0024);

a source of a cleaning gas 163, wherein the source of the cleaning gas 163 is connected to the plasma discharge chamber 13 (§ 0152, FIG. 5);

a piping 14 that links the reaction chamber 2 and the remote plasma discharge chamber 13 (abstract, FIG. 3); and

a valve 15 positioned in the piping 14, wherein an opening 22, 23 of the valve 15 is sized, when fully opened, substantially equal in width to an inner surface of the piping 14, and the valve 15 does not have projections, when fully opened, with respect to the inner surface of the piping 14 (§§ 0023, 0099, FIGS. 4A and 4B),

wherein energy coupled to the remote plasma discharge chamber 13 activates cleaning gas within the plasma discharge chamber 13, and the activated cleaning gas is exposed to the aluminum alloy wall and brought into the inside of the reaction chamber 2 through the piping 14 and changes solid substances adhered to the inside of the reaction chamber 2 as a consequence of film formation, to gaseous substances, thereby cleaning the inside of the reaction chamber 2 (§§ 0018, 0082).

Claim 19 further recites:

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The CVD device of Claim 14, wherein when the valve 15 is open, a cleaning gas can flow from the remote plasma discharge chamber 13 to the reaction chamber 2 without obstruction, and wherein the piping 14 is at least 1/2 inch in diameter (§ 0012).

Appellants reserve the right to separately argue individual claims of the above groups in subsequent continuing applications, with respect to the patentability of various dependent features not addressed herein.

## **VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL**

The Examiner has rejected Claims 1-3, 5, 6, 8-10, and 14-16 under 35 U.S.C. §103(a) as being unpatentable over Shang et al (EP 0697467, hereinafter "Shang ('467)"), in view of Igarashi et al. (U.S. Pat. No. 5,031,571, hereinafter "Igarashi"), Iyer et al. (U.S. Pat. No. 6,498,109, hereinafter "Iyer"), and Fong et al. (U.S. Pat. No. 5,812,403 and/or U.S. Pat. No. 5,969,831, hereinafter "Fong"). The Examiner has further rejected Claims 17-19 over the above references in view of Noble et al. (U.S. Pat. No. 6,450,116, hereinafter "Noble"). Claim 45 has been rejected over Shang ('467), Igarashi, Iyer and Fong, further in view of Ikeda et al. (U.S. Pat. No. 5,520,142, hereinafter "Ikeda").

## **VII. ARGUMENT**

### **A. *The Examiner's Asserted Rejections Regarding Independent Claims 1 and 9***

The Examiner has asserted that Shang ('467) teaches a chemical vapor deposition (CVD) device involving a deposition reaction chamber and a remote plasma discharge chamber for a cleaning gas. The Examiner has asserted that Igarashi teaches a capacitively coupled RF plasma power source and a remotely provided aluminum alloy chamber. The Examiner has asserted that Iyer teaches a remote plasma discharge chamber that can deliver power at a frequency between 10KHz and 200MHz. The Examiner has asserted that Fong teaches a valve (280, gate valve) configured as recited in the claims (Claim 1: a valve that has an opening that when fully open defines a pressure drop across the valve of less than about 0.25 Torr, or Claim 9: a valve that has



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an opening that is sized so that when the valve is fully opened the opening is substantially equal in width to an inner surface of the piping, and the valve does not have projections, when fully opened, with respect to the inner surface of the piping). The Examiner has generally asserted that one of skill in the art would have been motivated to combine Shang with Igarashi and Iyer because Igarashi teaches a "suitable" means to energize gas into plasma and Iyer teaches a "suitable" means for creating reactive species (see pages 3 and 4 of the Final Office Action). The Examiner has further asserted that one of skill in the art would have been motivated to use the specific valve alleged to be taught in Fong (as opposed to the other valves taught in the art) in order to open or block the activated cleaning gas passage, thereby controlling the flow of cleaning gas and/or preventing processing gases from entering the remote plasma chamber.

The Examiner has also asserted that teachings in other publications and patents, while teaching away from the presently claimed combination, are not relevant to the present analysis because these references are not actually employed in the current rejections.

**B. Legal Requirements for Establishing a Showing of Obviousness**

The Examiner bears the initial burden to establish and support a *prima facie* case of obviousness.<sup>1</sup> To establish a *prima facie* case of obviousness, there must be some suggestion or motivation, either in the references or in the knowledge generally available among those of ordinary skill in the art, to modify the reference.<sup>2</sup> Furthermore, to establish a *prima facie* case of obviousness, all the claim limitations must be taught or suggested by the prior art.<sup>3</sup> Finally, even

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<sup>1</sup> See *In re Rinehart*, 531 F.2d 1048, 189 U.S.P.Q. 143 (C.C.P.A. 1976).

<sup>2</sup> See *In re Vaack*, 947 F.2d 488 (Fed. Cir. 1991). "The references themselves, not the invention itself, must provide some teaching whereby the appellant's combination would have been obvious." *In re Forman*, 933 F.2d 982 (Fed. Cir. 1991); *Heidelberger Druckmaschinen AG v. Hantscho Commercial Products, Inc.*, 21 F.3d 1068 (Fed. Cir. 1993).

<sup>3</sup> See *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974).

once a *prima facie* case of obviousness is established, it can be rebutted in situations in which the art taught away from the claimed combination.<sup>4</sup>

**C. *Deficiencies in the Rejections.***

Appellants respectfully submit that the Examiner's reasons for continuing to reject the current claims are insufficient to provide a *prima facie* case of obviousness because (1) the rejections fail to cite a specific motivation for the asserted combinations, specifically for combining the valve allegedly taught in Fong with the other references, to reject the independent claims; (2) the Examiner explicitly ignores teachings away in the most relevant prior art with respect to the valve recitations; and (3) not all of the claim limitations are met inherently by the asserted combinations because the "gate valve" of Fang would not inherently meet the claim limitations related to pressure drop or full opening width.<sup>5</sup>

**1. *No Motivation for Why One of Skill in the Art Would Have Chosen the Specific Valve for the Specific Combination has been Provided.***

In the Final Office Action, the Examiner asserted that one of skill in the art would have been motivated to use the recited type of valve "in order to open or block the activated cleaning passage" (Final Office Action, page 4). While this may be adequate to motivate one of skill in the art to place a valve in the piping, it is not sufficient to demonstrate that the particular type of valve presently recited should be employed in the claimed combination. Appellants note that there must be some motivation in the prior art to select the claimed species or subgenus within what is taught by the prior art. See, *In re Deuel*, 51 F.3d 1552 at 1558-59 (Fed. Cir. 1995); *In re*

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<sup>4</sup> The totality of the prior art must be considered, and proceeding contrary to accepted wisdom in the art is evidence of nonobviousness. *In re Hedges*, 783 F.2d 1038, 228 USPQ 685 (Fed. Cir. 1986), and *In re Geisler*, 116 F.3d 1465, 1471, 43 U.S.P.Q.2d 1362, 1366 (Fed. Cir. 1997)).

<sup>5</sup> Appellants note that the two references cited in the rejection of some of the dependent claims, Ikeda and Noble, do not overcome the noted failings or alter the analysis with respect to the independent claims and are not relevant to the present arguments.

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Baird, 16 F.3d 380 at 382-83, 29 U.S.P.Q.2d at 1552 (Fed. Cir. 1994); and In re Bell, 991 F.2d 781 at 784, 26 U.S.P.Q.2d at 1531 (Fed. Cir. 1993).

Appellants note that numerous references taught a variety of valves in the same or similar location as Shang ('467). For example, Shang et al. (U.S. Pat. No. 5,788,778, hereinafter "Shang ('778)") taught that a needle valve is to be used between a remote plasma cleaning chamber and a CVD chamber (*i.e.*, exactly at the recited location).<sup>6</sup> Furthermore, other references taught numerous valve types (*e.g.*, Yin et al., PCT Pub. No. WO 99/20812, item 225, FIG. 4; Sun et al., Pat. Pub. No. 2002/0033183, item 62; and Fukuda et al., U.S. Pat. Pub. No. 2005/0139578, item 15) that were also employed.

What is clear from these references, and the art in general, is that one of skill in the art was aware of numerous types of valves that could be employed. However, what is not clear from the cited art and the Office Action is why one would have employed the valve in Fong over the valve in Shang ('778) or any one of the other numerous valves noted above. Appellants note that nothing in Shang ('467), Fong, or the other cited references actually teaches why or how the "gate valve" in Fong is useful, apart from it serving the same function as other valves. As such, none of the cited references (alone or when combined) appear to provide a motivation for why one would have selected valves with the presently recited features (low pressure drop or lack of internal projections when open) in the presently claimed combination.

Appellants submit that the Examiner is actually using hindsight, based on the current claims, to mold the combination of the elements taught in Shang ('467) into something that will cover the claimed invention. However, "[o]bviousness can not be established by hindsight combination to produce the claimed invention . . . . [I]t is the prior art itself, and not the appellant's achievement, that must establish the obviousness of the combination."<sup>7</sup> It is well

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<sup>6</sup> "Flow restrictor 59 may be, for example, a small orifice or a series of small orifices, although any device that creates a pressure differential, such as a reduction valve or a needle valve, could be employed." (Col. 5, lines 26-31)

<sup>7</sup> In re Dance, 160 F.3d 1339 (Fed. Cir. 1998). "Our case law makes clear that the best defense against the subtle but powerful attraction of a hindsight-based obviousness analysis is

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established that when a rejection for obviousness depends on a combination or modification of elements disclosed in prior art references, there must be motivation to combine or modify those particular elements in the prior art as a whole. "There must be evidence that 'a skilled artisan, confronted with the same problems as the inventors and with no knowledge of the claimed invention, would select the elements from the cited prior art references for combination in the manner claimed.'"<sup>8</sup> The Examiner has not provided any such motivation.

Indeed, it is very telling that the Examiner has provided no motivation in terms of the specific valve disclosed in Shang ('467); rather, the Examiner has merely suggested a motivation that would be equally applicable to any type of valve.<sup>9</sup> In essence, the Examiner has provided no more reason for the combination than that the valve of Fong could have been used in combination with the CVD device of Shang ('467). However, the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination.<sup>10</sup>

In light of the above, it is clear that, because the Examiner has not supplied a motivation to select the particular valve in the particularly claimed combination, a *prima facie* case of obviousness has not been established.

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rigorous application of the requirement for a showing of the teaching or motivation to combine prior art references." See, *In re Dembiczak*, 175 F.3d 994 (Fed. Cir. 1999); see also, *Ecolchem, Inc. v. Southern California Edison Co.*, 227 F. 3d 1361 (Fed. Cir. 2000).

<sup>8</sup> *In re Rouffet*, 149 F.3d 1350, 1357, 47 U.S.P.Q.2d 1453, 1456 (Fed. Cir. 1998); see also, *In re Werner Kotzab*, 217 F.3d 1365, 1371, 55 U.S.P.Q.2d 1313, 1317 (Fed. Cir. 2000) and *In re Dow Chemicals*, 837 F.2d 469, 473, 5 U.S.P.Q.2d 1529, 1531, (Fed. Cir. 1988) ("Both the suggestion [to combine] and the expectation of success, must be founded in the prior art, not in the appellant's disclosure.")

<sup>9</sup> This is not the situation where merely equivalent results can be obtained with use of now interchangeable features; rather, the Examiner has acknowledged that the presently claimed combination, including the specific valve, results in a superior device (Final Office Action, page 9).

**2. *It is Legal Error for the Examiner to Ignore Teachings in the Prior Art.***

The Examiner has improperly ignored clear teachings away from the presently claimed combination, in making the rejections. Indeed, the Examiner has explicitly ignored numerous relevant references that taught the value of restricting the flow of gas in the claimed context (*i.e.*, between a remote plasma for cleaning gas and a downstream CVD chamber) and therefore taught away from the application of the recited low pressure drop or fully opening valve. Indeed, the following findings of the Examiner are clearly legally incorrect:

- e. The argument that “The Prior Art Taught Away from the Use of a Through-Flow Valve in Cleaning” is moot because does not matter what the prior art, not used in the rejection, teaches. Only the teachings of the prior art used in the rejection are relevant.

(Final Office Action, page 9). Similarly, the Examiner also stated that:

- a. The arguments directed to Shang et al. U.S. Patent No. 5,788,778 are moot because Shang et al, US patent 5,788,778 is not used in the present rejections.

(Final Office Action, p. 8). Contrary to this finding, Appellants submit that the prior art, as a whole must be considered.<sup>11</sup> It is well established that the totality of the prior art must be considered, and that proceeding contrary to accepted wisdom in the art is evidence of nonobviousness. (See, *In re Dow Chemical Co.*, 837 F.2d 469, 473, 5 USPQ2d 1529, 1532 (emphasis added, Fed. Cir. 1988) (“...the full field of the invention must be considered... the person of ordinary skill is charged with knowledge of the entire body of technological literature, including that which might lead away from the claimed invention.”)).<sup>12</sup>

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<sup>10</sup> *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990).

<sup>11</sup> A prior art reference must be considered in its entirety, *i.e.*, as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F.2d 1540, 220 USPQ 303 (Fed. Cir. 1983), *cert. denied*, 469 U.S. 851 (1984).

<sup>12</sup> See also, *In re Hedges*, 783 F.2d 1038, 228 USPQ 685 (Fed. Cir. 1986)

In light of the clearly erroneous legal standard applied by the Examiner, and the clear teachings away discussed below, Appellants submit that, even if a *prima facie* case of obviousness had been established, it would have been rebutted by the clear teachings away in the art.

**3. *The Prior Art Taught Away from the Use of a Through-Flow Valve in Cleaning.***

The art of record specifically taught to restrict the flow between the two chambers during cleaning, often through the use of the valve itself. As such, the art taught away from a valve configured so as to minimize the interaction between the valve body and the flow path when open. The fact that this was the current understanding in the art at the time of the invention is noted in the present application (*see, e.g.*, ¶¶ 0009-0011 and 0042 of the '953 Application). Appellants note that none of the cited art contradicts this. Indeed, as detailed below, most of the references explicitly support this concept, explicitly or implicitly.

For example, U.S. Pat. No. 5,788,778 ("Shang, '778") teaches away from the presently recited valve. The '778 patent teaches the use of a "flow restrictor" to prevent the free flow of gas between a remote chamber and the deposition chamber (*see, e.g.*, "A flow restrictor 59 is employed in pipe 57. Flow restrictor 59 may be placed anywhere in the path between remote chamber 46 and deposition chamber 10." (col. 4, lines 48-50)). Indeed, the type of valve disclosed in Shang ('778), a "needle valve," is disclosed as useful because it creates a significant pressure differential. (col. 5, lines 22-30). Thus, the '778 patent clearly teaches creating a pressure differential in the piping between the remote plasma unit and the CVD chamber, while the presently recited valve features (low pressure drop or no internal projections when open) accomplish just the opposite, minimizing any pressure differential created when fully opened. Again, as noted above, in the Final Office Action the Examiner explicitly, and improperly, ignored the explicit teachings of Shang et al ('778). (Final Office Action, page 8). In light of this very clear teaching away, Appellants submit that even if a *prima facie* case had been established, it would have been rebutted.

Appellants note that Shang is not the only reference in the art that generally teaches the restriction of gas flow between these two chambers. For example, Sun et al. (U.S. Pat. Pub. No. 2002/0033183) actually teaches that the “valve” 62 is a flow restrictor which is used to maintain a desired pressure differential between the remote plasma chamber and the deposition chamber (*see, e.g.*, 0013). Thus, Sun also teaches away from a valve that has the recited features (low pressure drop or lack of internal projections when open). Additionally, U.S. Pat. No. 6,274,058 teaches a valve 80 that is positioned between a remote cleaning chamber and a processing chamber and is used to adjust and control the flow rate of the cleaning vapor. Thus, there are a number of references that not only teach that a valve designed and configured for restriction or control should be used, but explicitly teach that this ability to restrict or control the flow of the gas is an important aspect that a valve should possess.

In addition, the teachings in Fong do not appear to rebut the teachings in the above references. In particular, Fong supplies no advantages for using a “gate valve” and there is no other evidence of record as to why the skilled artisan might choose Fong’s valve over the numerous other types of valves in the art. Thus, Fong’s teachings certainly do not rebut the above noted teachings away from the claimed combination.

Furthermore, in addition to the above references that explicitly note specific aspects regarding the valves, there are also numerous references that teach aspects that show at best an indifference to features of the valve recited in the present claims. For example, Shang (‘467) teaches that a filter 56 should be placed between the remote chamber 46 and the processing chamber. It is noted that the use of filters in this location will result in the restriction of the flow of gas, making the presently recited type of valve (with low pressure drop on no internal projections when open) a pointless modification.

Appellants submit that the art, when considered as a whole, teaches away from the use of valves with the presently recited features in the recited apparatus because the art was focused on slowing, restricting, and controlling the flow, rather than using a device that minimized pressure differences on either side of the valve. Indeed, the benefits of the recited valves are opposite in nature to flow restricting valves or filters. As the art clearly taught that items that

obstructed/restricted the flow of gas were desirable and standard, the art taught away from a valve that “when fully open, defines a pressure drop across the valve of less than about 0.25 Torr” (Claim 1) or a valve that “is sized, when fully opened, substantially equal in width to an inner surface of the piping, and the valve does not have projections, when fully opened, with respect to the inner surface of the piping” (Claim 9).

**4. *The Examiner has not Demonstrated that the Claimed Valve is Inherently Taught by FIGs 6A and 3 of Fong***

The Examiner has asserted various teachings in Fong as allegedly teaching a valve as recited in the claims. In particular, the Examiner has asserted that one of skill in the art would interpret Figures 6A and 3 of Fong as teaching the presently claimed valve.<sup>13</sup> As noted above, there are a variety of valves, valve bodies, and ways of arranging each and not all of these options necessarily have the recited characteristics. In light of this, and the lack of any clear teaching in Fong, the Examiner has not established that Fong teaches the presently recited type of valve.

The cited sections of Fong (FIGs. 6a and 3) only teach the general concept of a “gate valve” at a particular location. However, the items in the figures are merely schematics of valves (partial block diagrams) and are largely silent in regard to the inner structure of the valves. Additionally, while a flow path is generally depicted as passing through the valve in Fong, there is no discussion or depiction regarding the valve body (the part of the valve that can obstruct the opening) or how the valve body relates to the opening in the opened or closed arrangements. The teaching of a flow path in a valve, without a teaching of the valve body, is not sufficient to teach or suggest the presence or desirability of the presently recited valve in the recited context. As

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<sup>13</sup> Independent Claim 1 recites, among other elements, “a valve positioned in the piping, wherein the valve has an opening that, when fully open, defines a pressure drop across the valve of less than about 0.25 Torr.” Independent Claim 9 recites, among other elements, “a valve positioned in the piping, wherein an opening of the valve is sized, when fully opened, substantially equal in width to an inner surface of the piping, and the valve does not have projections, when fully opened, with respect to the inner surface of the piping.”



such, Fong does not teach or suggest the presence of the particularly recited valve in the recited context.

At bottom, the Examiner believes that a "gate valve" inherently meets the limitations of Claims 1 (pressure drop of less than 0.25 mTorr when open) and Claim 9 (no internal projection and opening as wide as the piping). However, the fact that a certain characteristic may be present in the prior art is not sufficient to establish the inherency of that characteristic.<sup>14</sup> Rather, "[t]o establish inherency, the extrinsic evidence 'must make clear that the missing descriptive matter is necessarily present in the thing described in the reference... Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.'"<sup>15</sup> Despite these requirements, the Examiner has produced no evidence of such inherency.

While Appellants believe that this absence of teaching or suggestion is abundantly clear from the figures themselves (which are completely silent with regard to the valve body), Appellants previously submitted a declaration by one of skill in the art, Kiyoshi Satoh, that discusses how one of skill in the art would view the actual teachings of the relevant valve in Fong.

Mr. Satoh's signed Declaration (submitted in the Response dated January 12, 2007) supports the present and previous interpretations of Fong. In item 4 of the Declaration, Mr. Satoh states that Fong does not teach the recited valve. Mr. Satoh notes that the cited sections in Fong (Figures 3 and 6a) merely demonstrate a schematic of the concept of a gate valve and not the particularly recited valve. In particular, Figure 3 merely represents the valve 280 as a

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<sup>14</sup> *In re Rijckaert*, 9 F.3d 1531, 1534, 28 USPQ2d 1955, 1957 (Fed. Cir. 1993) (reversed rejection because inherency was based on what would result due to optimization of conditions, not what was necessarily present in the prior art); *In re Oelrich*, 666 F.2d 578, 581-82, 212 USPQ 323, 326 (CCPA 1981).

<sup>15</sup> *In re Robertson*, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999). See also, *Ex parte Levy*, 17 USPQ2d 1461, 1464 (Bd. Pat. App. & Inter. 1990) "In relying upon the theory of inherency, the examiner must provide a basis in fact and/or technical reasoning to reasonably support the determination that the allegedly inherent characteristic necessarily flows from the teachings of the applied prior art."

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schematic block with a fluid passage 293 passing through it. Furthermore, the Declaration confirms that Fong does not disclose the actual valve body or how it is involved with the valve opening. Thus, there is no disclosure regarding the actual position of the valve body when the valve is fully opened. The Declaration also confirms that Figure 6a simply represents the valve 280 as a schematic block or "black box" with a passageway. Again, there is no depiction of the actual valve body. The Declaration further confirms that there is no actual or inherent teaching in Fong et al. that 1) the valve is configured so that, when fully opened, the opening through the valve is substantially equal in width to an inner surface of the piping and/or the valve does not have projections with respect to the inner surface of the piping or 2) that the pressure drop across the valve is less than 0.25 Torr.

Mr. Satoh's declaration clearly establishes that, contrary to the unsupported assertions made in the Office Actions, Fong does not necessarily teach the relevant valve in the two cited figures because there is no clear disclosure of a valve body, how it works, or where the valve body is located when the valve is opened.

In light of this, Appellants submit that not every element has been taught by the cited art. As such, a *prima facie* case of obviousness has not been established by the present rejection.

**D. *The Examiner has not Addressed Each and Every Feature of Claim 19***

It is noted that Claim 19 recites the element that the device be capable of allowing the cleaning gas to flow from the remote plasma discharge chamber to the reaction chamber without obstruction. Appellants note that this element has not been addressed or acknowledged in the Office Action. Additionally, it is noted that the mixing block in Fong (item 273) and the filter in Shang ('467, item 56) would prevent this element from being present, as recited in the Claims. The Examiner has not even attempted to exclude these elements from the asserted combination, which would be required to meet this claim. Thus, for at least this reason, a *prima facie* case of obviousness has not been established in regard to Claim 19.

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### **VIII. CONCLUSION**

In summary, because the Examiner has not provided an adequate motivation for combining the particularly recited valve in the particularly recited combination, the Examiner has failed to demonstrate a *prima facie* showing of obviousness. Additionally, assuming, *in arguendo*, that a *prima facie* case had been established, it is clear that the art generally taught away from aspects relating to the claimed combination. As such, any such *prima facie* showing of obviousness has been rebutted by the actual teachings away in the prior art. Finally, the Examiner has further failed to establish a *prima facie* showing of obviousness because each of the elements has not been taught by the cited references.

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#### **IX. SUMMARY OF CLAIMS APPENDIX**

Attached hereto as Appendix A is a copy of the finally rejected claims in the present case.

#### **X. SUMMARY OF EVIDENCE APPENDIX**

Attached hereto as Appendix B is a copy of Shang (U.S. Pat. No. 5,788,778), U.S. Pat. No. 6,274,058, Sun (U.S. Pat. Pub. No. 2002/0033183), Yin et al., (PCT Pub. No. WO 99/20812), Fukuda (U.S. Pat. Pub. No. 2005/0139578), and Shang (EP 0697467)) references of record and discussed in the Response mailed August 18, 2006. Additionally, a copy of the signed declaration, submitted to the Examiner in the Response dated January 12, 2007 is also included.

#### **XI. SUMMARY OF RELATED PROCEEDINGS APPENDIX**

No related appeal proceedings are known.

Please charge any additional fees, including any fees for additional extension of time, or credit overpayment to Deposit Account No. 11-1410.



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**APPENDIX A**  
**(Claims as finally rejected)**

1. **(Previously presented)** A chemical vapor deposition (CVD) device comprising  
a deposition reaction chamber;  
a plasma discharge chamber that is provided remotely from the reaction chamber;  
wherein the plasma discharge chamber comprises 1) a wall that comprises an aluminum alloy, wherein the wall is exposed to plasma discharge, and 2) a radio-frequency (RF) energy source connected to plasma discharge chamber electrodes;  
a source of a cleaning gas, wherein the source of the cleaning gas is connected to the plasma discharge chamber;  
a piping that links the reaction chamber and the remote plasma discharge chamber; and  
a valve positioned in the piping, wherein the valve has an opening that, when fully open, defines a pressure drop across the valve of less than about 0.25 Torr,  
wherein energy coupled to the remote plasma discharge chamber activates cleaning gas within the plasma discharge chamber, and the activated cleaning gas is exposed to the aluminum alloy wall and brought into the inside of the reaction chamber through the piping and changes solid substances adhered to the inside of the reaction chamber as a consequence of film formation, to gaseous substances, thereby cleaning the inside of the reaction chamber.

2. **(Original)** The CVD device according to Claim 1, wherein the activated cleaning gas comprises fluorine active species.

3. **(Previously presented)** The CVD device of Claim 2, wherein the internal surface of the piping comprises a metal not corroded by the activated cleaning gas species, wherein said metal is selected from the group consisting of: aluminum and aluminum alloy.

4. **(Cancelled).**

5. **(Previously presented)** The CVD device of Claim 1, wherein the piping and the valve are configured so that no appreciable pressure loss arises in the piping and at the valve when the cleaning gas flows between the remote plasma discharge chamber and the reaction chamber.

6. **(Original)** The CVD device of Claim 5, wherein the activated cleaning gas comprises fluorine active species and an inner surface of the valve is made of fluorine-passivated aluminum.

7. **(Cancelled).**

8. **(Previously presented)** The CVD device of Claim 1, wherein the pressure drop across the valve when fully open is less than about 0.1 Torr.

9. **(Previously presented)** A chemical vapor deposition (CVD) device comprising:

a deposition reaction chamber;

a plasma discharge chamber that is provided remotely from the reaction chamber;

wherein the plasma discharge chamber comprises 1) a wall that comprises an aluminum

alloy, wherein the wall is exposed to plasma discharge, and 2) a radio-frequency (RF) energy source connected to plasma discharge chamber electrodes;

a source of a cleaning gas, wherein the source of the cleaning gas is connected to the plasma discharge chamber;

a piping that links the reaction chamber and the remote plasma discharge chamber; and

a valve positioned in the piping, wherein an opening of the valve is sized, when fully opened, substantially equal in width to an inner surface of the piping, and the valve does not have projections, when fully opened, with respect to the inner surface of the piping,

wherein energy coupled to the remote plasma discharge chamber activates cleaning gas within the plasma discharge chamber, and the activated cleaning gas is exposed to the aluminum alloy wall and brought into the inside of the reaction chamber through the piping and changes solid substances adhered to the inside of the reaction chamber as a consequence of film formation, to gaseous substances, thereby cleaning the inside of the reaction chamber.

10. **(Previously presented)** The CVD device of Claim 1, wherein the piping and the valve are heated to a temperature effective to prevent deposition of the cleaning gas.

11. **(Withdrawn)** The CVD of Claim 1, further comprising a support provided within the reaction chamber, configured to support an object to be processed, and a gas-emitting plate provided at a position facing the support within the reaction chamber in order to supply

reaction gas to the object to be processed to form a film on the object to be processed, wherein the activated cleaning gas is supplied through piping into the reaction chamber from holes provided on the gas-emitting plate.

12. **(Withdrawn)** The CVD device of Claim 11, wherein the gas-emitting plate is connected to a source of power to form an *in situ* plasma electrode for plasma CVD within the reaction chamber.

13. **(Withdrawn)** The CVD device of Claim 11, further comprising a gas conduit communicating with a source of reaction gas, wherein one end of the gas conduit is linked to the piping at a predetermined position between the valve and the gas-emitting plate.

14. **(Original)** The CVD device of Claim 1, wherein the piping is straight between the remote plasma discharge chamber and the reaction chamber.

15. **(Previously presented)** The CVD device of Claim 1, wherein the energy activating the cleaning gas has a frequency between about 300 kHz and 500 kHz.

16. **(Original)** The CVD device of Claim 14, wherein the energy activating the cleaning gas has a power between about 1,500 W and 3,000 W.

17. **(Original)** The CVD device of Claim 1, further comprising a reaction gas inlet and a reaction gas outlet defining a horizontal flow across a substrate surface upon which material is deposited within the reaction chamber.

18. **(Original)** The CVD device of Claim 17, wherein the piping opens into the reaction chamber downstream of the inlet and upstream of a substrate support configured for supporting a substrate within the chamber.



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19. **(Previously presented)** The CVD device of Claim 14, wherein when the valve is open, a cleaning gas can flow from the remote plasma discharge chamber to the reaction chamber without obstruction, and wherein the piping is at least 1/2 inch in diameter.

20-44. **(Cancelled).**

45. **(Previously presented)** The CVD device of Claim 1, wherein the wall made of aluminum alloy of the remote plasma discharge chamber comprises anodized aluminum alloy.

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**APPENDIX B**  
**EVIDENCE APPENDIX**

Appendix B includes the following documents:

Shang (U.S. Pat. No. 5,788,778),

U.S. Pat. No. 6,274,058,

Sun (U.S. Pat. Pub. No. 2002/0033183),

Yin et al., (PCT Pub. No. WO 99/20812),

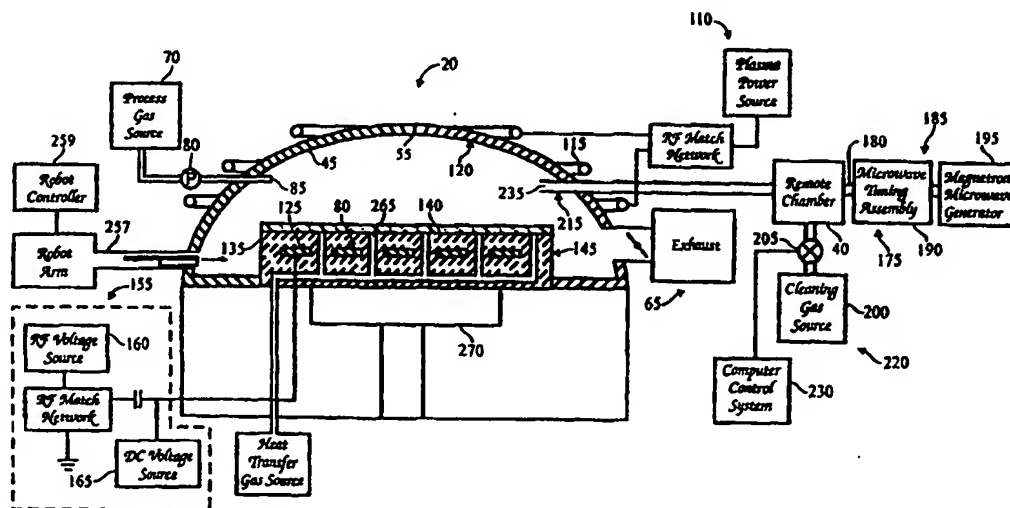
Fukuda (U.S. Pat. Pub. No. 2005/0139578),

Shang (EP 0697467))

Signed declaration, submitted to the Examiner in the Response dated January 12, 2007.

<p>(51) International Patent Classification <sup>6</sup> : C23C 16/44</p>	<p>A1</p>	<p>(11) International Publication Number: WO 99/20812</p>	<p>(43) International Publication Date: 29 April 1999 (29.04.99)</p>
<p>(21) International Application Number: PCT/US98/21806</p> <p>(22) International Filing Date: 14 October 1998 (14.10.98)</p> <p>(30) Priority Data: 08/955,181 21 October 1997 (21.10.97) US</p> <p>(71) Applicant: APPLIED MATERIALS, INC. [US/US]; 3050 Bowers Avenue, Santa Clara, CA 95054 (US).</p> <p>(72) Inventors: YIN, Gerald, Zheyao; 10132 Bilich Place, Cupertino, CA 95014 (US). QIAN, Xue-Yu; 230 Rose Drive, Milpitas, CA 95035 (US). LEAHEY, Patrick, L.; 1715 Parkside Avenue, San Jose, CA 95125 (US). MOHN, Jonathan, D.; 13179 Paseo Presada, Saratoga, CA 95070 (US). CHOW, Waiching; 35875 Vivian Place, Fremont, CA 94536 (US). CHEN, Arthur, Y.; 744 Bodega Court, Fremont, CA 94539 (US). SUN, Zhi-Wen; 126 Destry Court, San Jose, CA 95136 (US). HATCHER, Brian, K.; 361 Springpark Circle, San Jose, CA 95136 (US).</p> <p>(74) Agents: BERNADICOU, Michael, A. et al.; Blakely, Sokoloff, Taylor &amp; Zafman LLP, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025 (US).</p>		<p>(81) Designated State: JP.</p> <p><b>Published</b>  <i>With international search report.          Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: METHOD FOR CLEANING AN ETCHING CHAMBER



**(57) Abstract**

An apparatus (20) and process for treating and conditioning an etching chamber (30), and cleaning a thin, non-homogeneous, etch residue on the walls (45) and components of the etching chamber (30). In the etching step, a substrate (25) is etched in the etching chamber (30) to deposit a thin etch residue layer on the surfaces of the walls and components in the chamber. In the cleaning step, cleaning gas is introduced into a remote chamber (40) adjacent to the etching chamber (30), and microwave or RF energy is applied inside the remote chamber to form an activated cleaning gas. A short burst of activated cleaning gas at a high flow rate is introduced into the etching chamber (30) to clean the etch residue on the walls (45) and components of the etching chamber. The method is particularly useful for cleaning etch residue that is chemically adhered to ceramic surfaces in the chamber, for example surfaces comprising aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, zirconium oxide, or mixtures thereof.

## APPENDIX B

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
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## METHOD FOR CLEANING AN ETCHING CHAMBER

BACKGROUND

The present invention relates to an etching chamber and a method for etching substrates and for cleaning and conditioning the surfaces of the chamber.

In the manufacture of integrated circuits, silicon dioxide, polysilicon, tungsten silicide, and metal layers on a substrate, are etched in predefined patterns to form gates, vias, contact holes, or interconnect lines. In the etching process, a patterned mask layer, such as an oxide hard mask or a photoresist layer, is formed on the substrate using conventional photolithographic methods, and the exposed portions of the substrate are etched by capacitive or inductively coupled plasmas. Commonly used etchant halogen gases include fluorinated gases such as  $\text{CF}_4$ ,  $\text{SF}_6$ , and  $\text{NF}_3$ ; chlorinated gases such as  $\text{Cl}_2$ ,  $\text{CCl}_4$ ,  $\text{SiCl}_4$ , and  $\text{BCl}_3$ ; and brominated gases such as  $\text{HBr}$ ,  $\text{Br}$ , and  $\text{CH}_3\text{Br}$ .

In the etching process, the etching chamber is contaminated by a thin etch residue layer that deposits on the walls and other components in the chamber. The composition of the etch residue layer depends upon the etchant gases, the material being etched, and the composition of the mask layer applied to the substrate. When silicon is etched, silicon-containing gaseous species vaporized or sputtered from the substrate are present in the chamber environment; and when metal species are etched, metal ions are present in the chamber environment. The resist or mask layer on the substrate is also partially etched away by the etchant gas to form gaseous hydrocarbon or oxygen species in the chamber. These different species combine within the chamber

environment to form polymeric byproducts containing hydrocarbons, elemental silicon or metal species, and often also contain oxygen, nitrogen or boron. The polymeric byproducts deposit as thin etch residue layers on the walls and components in the chamber. The composition of the etch residue layer can vary  
5 widely across the chamber depending upon the composition of the localized gaseous environment.

The non-homogeneous, etch residue layer formed in the etching process has to be periodically cleaned to prevent contamination of the  
10 substrate, and to provide internal chamber surfaces that have consistent and homogeneous chemical compositions and surface functionality, otherwise the etching processes performed in the chamber can vary widely in etching properties. In a traditional wet cleaning process, an operator periodically shuts down the etching machine, and uses an acid or solvent to scrub down the  
15 chamber walls. In the competitive semiconductor industry, the increased per substrate cost arising from downtime of the etching chamber, is undesirable. Also, because the wet cleaning process is manually performed by an operator, it often varies from one session to another, and limits the reproducibility of the etching process conducted in the chamber.

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Another commonly used etch chamber cleaning method uses an in-situ ionized plasma which is generated inside the etch chamber, to clean the chamber walls. However, the in-situ ionized plasma species are highly energetic and can rapidly erode the chamber walls and chamber components. It is  
25 expensive to periodically replace the eroded parts and components in the chamber. Also, surface erosion of the chamber surfaces and components by the energetic plasma species, can often result in the instability and lack of reproducibility of subsequent plasma etching process steps performed in the chamber. For example, variations in the concentration, type, or surface  
30 functional bonds or chemical groups on the exposed surfaces of the walls and

components in the chamber, affect the sticking coefficient of gases and vapors on these surfaces, and consequently, the gaseous plasma etching chemistry in the chamber. Chamber surfaces having excessively active surface functional groups can deplete the concentration of gaseous chemical species needed to etch the substrate. Furthermore, the relatively high plasma power levels required to achieve acceptable cleaning rates tend to generate residue byproducts that damage system components and which cannot be removed except by physically wiping the internal surfaces of the chamber. For example,  $\text{NF}_3$  plasma used to clean aluminum chamber surfaces results in formation of  $\text{Al}_x\text{F}_y$  compounds that cannot be etched away by nonchemical processes. As another example,  $\text{NF}_3$  gas that is used to clean  $\text{Si}_3\text{N}_4$  CVD deposition systems result in formation of  $\text{N}_x\text{H}_y\text{F}_z$  compounds that are deposited on the exhaust or vacuum pump and affect the reliability of the exhaust pump.

15 In chemical vapor deposition (CVD) processes, cleaning gases that are activated by microwaves in a remote chamber and further energized by capacitive coupled plasmas in-situ in the CVD chamber, have been used to clean the relatively thick and homogeneous CVD deposit layers formed in these chambers. In a typical CVD process, reactive gases are used to deposit a layer of material, such as aluminum or silicon dioxide, on the substrate. During the deposition process, the CVD deposits that are formed on the chamber walls and surfaces are often as thick as the CVD layers deposited on the substrate. The CVD deposits also have a relatively uniform and homogeneous chemical composition that corresponds to the material deposited on the substrate. The thick and chemically homogeneous CVD deposits can be cleaned by a high power microwave and capacitive coupled plasma, as for example, described in U.S. Patent No. 5,449,411, which is incorporated herein by reference. In another example, commonly assigned European Patent No. 555 546 A1 discloses a process for CVD of silicon and removal of silicon deposits from the walls of the CVD chamber using a microwave plasma of  $\text{NF}_3$  or  $\text{CF}_4/\text{O}_2$ .

Similarly, German Patent No. 4,132,559 A1 also describes a method of cleaning a CVD deposition chamber using a remotely generated microwave plasma of  $\text{NF}_3$ .

5                    However, the CVD chamber cleaning processes for cleaning thick and stoichiometrically homogeneous CVD deposits in deposition chambers are not suitable for cleaning the thin, variable composition, etch residue layers formed on the inner surfaces of etching chambers. The thin etch residue layers make it difficult to stop the cleaning process, after removal of the residue layer, 10 resulting in extensive erosion of the underlying chamber surfaces. Also, the variable chemical stoichiometry and composition of the etch residue layers at different portions of the chamber make it difficult to clean all of the residue. For example, the etch residue formed near the chamber inlet or exhaust is often thinner and has a higher concentration of etchant gas species (or of material 15 being etched) than etch residue formed near the substrate which typically contains a higher concentration of polymeric or oxide mask species. It is extremely difficult to generate a plasma or gas that uniformly etches away the variable stoichiometric composition etch residue without either eroding the chamber walls below the thin soft residue layers, or conversely, failing to clean- 20 off thick and chemically hard residue layers. For these reasons, known methods of cleaning CVD deposits in deposition chambers are ineffective at cleaning the ultra thin and compositional variant etch residue layers formed on the walls and components of etching chamber without damaging or eroding the underlying walls and component surfaces.

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                  Thus, it is desirable to have a treatment process that maximizes the chemical reactivity of the cleaning gas to etchant deposits in an etching chamber and that minimizes the chemical reactivity of the cleaning gas to the exposed surfaces in the chamber. It is further desirable to have a method for 30 treating the etching chamber that removes chemically adhered etchant deposits



from chemically active surfaces in the chamber and restores the original chemical reactivity and surface functional groups of these surfaces. It is further desirable for the chamber cleaning process to remove etch residues having variable thickness and non-uniform chemical stoichiometry, without excessive erosion of the chamber walls and components.

### SUMMARY

The present invention provides an apparatus and method of etching a substrate in an etching chamber, cleaning a non-homogeneous, variable composition, etch residue layer from the walls and components of an etching chamber, and treating and conditioning ceramic surfaces in the chamber to provide highly consistent and reproducible etching performance. In the etching step, a substrate is etched in the etching chamber thereby depositing a thin etch residue layer on the surfaces of the walls and components in the etching chamber. In the cleaning step, cleaning gas is activated in a remote chamber adjacent to the etching chamber, for example, by applying microwave or RF energy in the remote chamber. The activated cleaning gas is introduced into the etching chamber to clean the etch residue on the walls and components of the etching chamber. It has been discovered that this method is particularly useful for cleaning etch residue strongly adhered to, or chemically reacted with, ceramic surfaces comprising aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, zirconium oxide, or mixtures thereof.

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When etching certain materials, for example, silicon-containing layers, a relatively thin etch residue layer containing primarily polymeric, oxygen, and silicon-containing species, and having a thickness of about 0.01 to about 1 micron is formed on the chamber walls and surfaces. It has been discovered that such an etchant layer can be efficiently removed by a high flow rate, short

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burst of activated cleaning gas introduced into the etching chamber at a flow rate  $F_R$  equivalent to a rate of about 200 to about 2000 sccm for a chamber having a volume of about 40,000 cm<sup>3</sup> for a time period of about 0.5 to about 100 seconds to clean the etch residue, substantially without eroding the walls and components in the chamber.

Preferably, the cleaning process is performed while or immediately after, the substrate is being transporting out of the etching chamber, to increase throughput from the etching chamber. Preferably, a short burst of a high flow rate of activated cleaning gas is introduced into the etching chamber for a short time period, while substrate is being transported in or out of the chamber, to clean and condition the surfaces in the chamber without eroding chamber surfaces or substrate surfaces. Another substrate is then transported into the chamber and the etching, transportation, and cleaning and conditioning steps are repeated, until the substrate supply is exhausted. In a preferred version, the remote chamber is maintained at a higher pressure than the etch chamber, to provide a more laminar flow of cleaning gas along the sidewalls and surfaces of the chamber.

It has further been discovered, in accordance with another aspect of the present invention, that superior cleaning and conditioning of etching chamber surfaces that are highly reactive to etch residue is achieved by introducing the activated gas into the chamber in multiple and discrete stages. The multicycle conditioning process comprises (i) a first stage, in which a first activated cleaning gas formed by maintaining the gas activator in the remote chamber at a first power level, is introduced into the etching chamber; and (ii) at least one second stage, in which a second activated cleaning gas formed by maintaining the gas activator in the remote chamber at a second power level different from the first power level, is introduced into the etching chamber. The cleaning gas in the first stage contains a more dissociated and chemically

reactive species that removes the hard and thick etch residues at the chamber walls and components near the substrate. The cleaning gas in the second cleaning stage is activated at a lower power level to more gently treat and condition surfaces such as ceramic surfaces. The duration of each cleaning stage is from about 0.5 to about 100 seconds, and more preferably, from about 0.5 to about 24 seconds. The multicycle process can be repeated a sufficient number of times to treat the chamber walls and reduce the concentration of etch residue to the desirable level.

10                   In yet another aspect, the present invention is to an etching apparatus comprises an etching chamber having a process gas inlet for introducing process gas into the chamber, a plasma generator for forming a plasma from the process gas for etching a substrate, and an exhaust system for exhausting the spent process gas from the etching chamber. A remote chamber  
15                   adjacent to the etching chamber is used to generate an activated cleaning gas. A gas distribution system comprises (i) a gas conduit for transporting the activated cleaning gas from the remote chamber to the etching chamber, (ii) a gas flow distributor for directing the flow of activated cleaning gas substantially parallel, and adjacent to, one or more internal surfaces of the chamber, and  
20                   (iii) a gas flow regulator for regulating the flow of activated cleaning gas into the gas flow distributor. Preferably, the gas flow distributor has nozzles positioned adjacent to surfaces in the chamber that have thicker etch residue layers, for directing the flow of activated cleaning gas to these regions to preferentially remove the thicker etch residue layers without eroding portions of the chamber  
25                   having thinner etch residue layers.

DRAWINGS

5        These and other features, aspects, and advantages of the present invention will be better understood from the following drawings, description and appended claims, which illustrate examples of the invention. While the description and drawings below illustrate exemplary features of the invention, it is to be understood that each of the features can be used in the invention in general, not merely in the context of the particular drawings, and the invention includes any combination of these features.

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      Figure 1 is a sectional schematic side view of an etching apparatus of the present invention;

15        Figure 2 is a flowchart of the process steps used to etch substrates and clean and condition the surface walls of the etching apparatus;

      Figure 3 is a sectional schematic side view of another version of an etching apparatus of the present invention;

20        Figure 4 is a sectional schematic side view of another version of an etching apparatus of the present invention;

      Figure 5 is a sectional schematic view of another version of an etching apparatus of the present invention; and

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      Figure 6 is a sectional schematic view of another version of an etching apparatus of the present invention.

DESCRIPTION

An apparatus 20 suitable for etching a substrate 25 according to the present invention, as schematically illustrated in Figure 1, comprises an enclosed process chamber 30 defining a process zone for processing the substrate, a remote chamber 40 for forming an activated cleaning gas, and a load-lock transfer area (not shown) maintained at low pressure for holding a cassette of substrates. The particular embodiment of the apparatus 20 shown herein is suitable for processing of semiconductor substrates 25 is provided only to illustrate the invention and should not be used to limit the scope of the invention. Particular features of the apparatus 20 are described in U.S. patent application serial no. 08/597,445, entitled "RF Plasma Reactor with Hybrid Conductor and Multi-Radius Dome Ceiling," filed on February 2, 1996; and in U.S. patent application serial no. 08/389,889, filed on February 15, 1993 -- both of which are incorporated herein by reference. The enclosed chamber 30 has sidewalls 45 and a bottom wall 50 fabricated from any one of a variety of materials including metals, ceramics, glasses, polymers, and composite materials. The process zone defined in the etching chamber 30 is directly above and surrounds the substrate 25 and comprises a volume of at least about 10,000 cm<sup>3</sup>, and more preferably about 10,000 to about 50,000 cm<sup>3</sup>. Metals commonly used to fabricate the enclosed chamber 30 include aluminum, anodized aluminum, "HAYNES 242," "Al-6061," "SS 304," "SS 316," and INCONEL, of which anodized aluminum is preferred.

The process zone comprises a ceiling 55 that is flat or rectangular shaped, arcuate, conical, dome-shaped, or multiradius dome shaped. Preferably, the ceiling 55 is dome-shaped to provide a uniform distribution of plasma source power across the entire volume of the plasma process zone to increase dissociation of the etchant gas within the plasma zone, as for example described in U.S. patent application Serial No. 08/596,960, entitled "Plasma

Process for Etching Multicomponent Alloys," filed on February 5, 1996, to Ma et al., which is incorporated herein by reference. The dome-shaped ceiling 55 reduces dissociated ion recombination losses near the substrate 25 so that plasma ion density is more uniform across the substrate than with a flat ceiling. This is because ion recombination losses are affected by the proximity of the ceiling 55, and the dome-shaped ceiling is further from the substrate center 60 than a flat ceiling. The dome ceiling 55 can be planar (i.e., flattened dome), conical, truncated conical, cylindrical, or other combination of such shapes, that provides a dome shaped surface above the substrate 25.

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Process gas is introduced into the chamber 30 through a gas distribution system 65 that includes a process gas supply 70 and a gas flow control system 75 that operates gas flow meters 80. The gas distribution system 65 can comprise gas outlets 85 located peripherally around the substrate 25 (as shown), or a showerhead mounted on the ceiling of the chamber 30 with outlets therein (not shown). Spent process gas and etchant byproducts are exhausted from the process chamber 30 through an exhaust system 90 (typically including a 1000 liter/sec roughing pump) capable of achieving a minimum pressure of about  $10^{-3}$  mTorr in the chamber 30. A throttle valve 95 is provided in the exhaust 90 to control the flow of spent process gas and the pressure of process gas in the chamber 30. Preferably, an asymmetric pumping channel 100 is used to pump gases out of the chamber 30 to provide a more symmetrical and uniform distribution of gaseous species around the surface 105 of the substrate.

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A plasma is formed from the process gas introduced into the chamber 30, using a plasma generator 110 that couples an electric field into the process zone of the chamber. A suitable plasma generator 110 comprises an inductor antenna 115 consisting of one or more inductor coils having a circular symmetry with a central axis coincident with the longitudinal vertical axis that

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extends through the center of the process chamber 30 and perpendicular to the plane of the substrate 25. Preferably, the inductor antenna 115 comprises solenoid coils having from 1 to 10 turns, and more typically from 2 to 6 turns. The arrangement and number of solenoid coils are selected to provide the  
5 desired product of current and antenna turns  $(d/dt)(N \cdot I)$  near the ceiling 55 to provide a strong inductive flux linkage with close coupling to the plasma and therefore greater plasma ion density in the plasma zone adjacent to the substrate 25, as described in U.S. patent application no.08/648,254. When the inductor antenna 115 is positioned near the dome ceiling 55, the ceiling of the  
10 chamber 30 comprises dielectric material which is transparent to RF fields, such as a slab of machined silicon dioxide or tiles of silicon or silicon dioxide bonded to one another to provide a curved shape. Preferably, the inductor coil 115 wrapped around the sidewall 45 of the process chamber 30 is a multiradius dome-shaped inductor coil having a "flattened" dome shape that provides  
15 increased plasma ion density directly over the substrate center 60 because ion density is affected by local ionization near the inductor coil 115, and a multiradius inductor coil is closer to the substrate center 60 than a hemispherical coil. In another preferred embodiment, the ceiling 55 comprises a multiradius dome having at least a center radius  $R$  and a corner radius  $r$ , wherein  
20  $r$  is less than the center radius  $R$  and  $R/r$  is from about 2 to about 10.

The plasma formed in the plasma zone can also be enhanced using magnetically enhanced reactors, in which a magnetic field generator (not shown), such as a permanent magnet or electromagnetic coils, are used to apply  
25 a magnetic field in the plasma zone to increase the density and uniformity of the plasma. Preferably, the magnetic field comprises a rotating magnetic field with the axis of the field rotating parallel to the plane of the substrate 25, as described in U.S. Patent No. 4,842,683, issued June 27, 1989, which is incorporated herein by reference. The magnetic field in the chamber 30 should  
30 be sufficiently strong to increase the density of the ions formed in the plasma,

and sufficiently uniform to reduce charge-up damage to features such as CMOS gates. Generally, the magnetic field as measured on the surface 105 of the substrate is less than about 500 Gauss, more typically from about 10 to about 100 Gauss, and most typically from about 10 Gauss to about 30 Gauss.

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In addition to the inductor antenna 115, one or more process electrodes can be used to accelerate or energize the plasma ions in the chamber 30. The process electrodes include a first electrode 120 forming a wall of the process chamber 30, such as the ceiling 55 and/or sidewalls 45 of the chamber. The first electrode 120 is capacitively coupled to a second electrode 125 below the substrate 25. An electrode voltage supply 155 supplies an RF potential that maintains the first and second electrodes 120, 125 at different electrical potentials relative to one another. The frequency of the RF voltage applied to the inductor antenna 115 is typically about 50 KHz to about 60 MHz, and more typically about 13.56 MHz; and the power level of RF voltage applied to the antenna is about 100 to about 5000 Watts.

The enclosed chamber 30 comprises one or more ceramic surfaces that serve different functions. For example, in one preferred embodiment, the walls 45, 50, 55 of the process chamber are coated with a ceramic material, such as boron carbide, boron nitride, silicon, silicon oxide, silicon carbide, or silicon nitride, to protect the walls from chemically erosion in particular etchant gas compositions. For example, boron carbide is useful for protecting sidewalls 45 of chambers from erosion in fluorinated gaseous environments. As another example, sapphire (aluminum oxide) gas distribution plates can be used to release process gas into the chamber 30.

Another ceramic surface useful in the process chamber 30 is that of a monolithic ceramic member 135 having a ceramic receiving surface 140 for receiving a substrate 25 thereon. Suitable ceramic materials include one or

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more of aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide. The ceramic member 135 is fabricated from a low porosity ceramic having a porosity of less than about 10%. The thermal conductivity of the dielectric material preferably comprises a high conductivity of about 80 to about 240 Watts/m K, for example, diamond or aluminum nitride. The second electrode 125 is embedded in the ceramic member 135 so that ceramic material completely surrounds the second electrode to form a unitary monolithic ceramic member. The second electrode 125 is fabricated from a conductive metal such as aluminum, copper, gold, molybdenum, tantalum, titanium, tungsten, and alloys thereof, and more preferably from a high melting point refractory metal, such as tungsten, tantalum or molybdenum, which allows thermal sintering of the ceramic member 135 with the embedded electrode 125 therein. The ceramic member 135 with the embedded electrode 125 can be fabricated by isostatic pressing, hot pressing, mold casting, or tape casting, from a mixture of ceramic powders and a low concentration of organic binder material.

The embedded second electrode 125 in the unitary monolithic ceramic member 135, is the sole conductor to which a "hot" RF potential is applied, with the other electrodes in the chamber 30 maintained at different potentials, including electrical ground or floating potentials, relative to the second electrode 125. Because it is embedded in the unitary ceramic member 135, the second electrode 125 does not have to be electrically isolated from the chamber 30 by additional insulator shields, thereby reducing the parasitic capacitance impedance loads in the chamber 30 that would otherwise result between the second electrode 125 and the grounded chamber walls 45, 50. Also, because there is no insulator shield in the chamber 30, the active area of the second electrode 125 can be increased to cover an area having a diameter that extends across the entire chamber bottom 50, providing a larger active

electrode area than conventional cathodes. The second electrode 125 also serves as an electrostatic chuck 145 that generates an electrostatic charge for electrostatically holding the substrate 25 to the receiving surface 140 of the ceramic member 135 using a DC chucking voltage applied through an electrical conductor 150 inserted through the ceramic member 135 to connect to the second electrode 125.

The first and second electrodes 120, 125 are electrically biased relative to one another by the electrode voltage supply 155 that includes an AC voltage 160 supply for providing a plasma generating RF voltage to the second electrode 125, and a DC voltage supply 165 for providing a chucking voltage to the electrode 125. The AC voltage supply 160 provides an RF generating voltage having one or more frequencies from 13.56 MHz to 400 KHz to form a capacitively coupled plasma in the chamber 30. The power level of the RF bias current applied to the electrode 125 is typically from about 50 to about 3000 Watts. A separate DC voltage is applied to the electrode 125 to form an electrostatic charge that holds the substrate 25 to the chuck 145. The RF power is coupled to a bridge circuit and an electrical filter to provide DC chucking power to the electrode 125.

The etching apparatus 20 further comprises a remote chamber 40, such as a quartz tube, adjacent and connected to the process zone of the etching chamber 30 via a gas conduit 170. The remote chamber 40 comprises a gas activator 175 that is used to provide a microwave or RF energy in the chamber 30, to activate the cleaning gas by ionization or dissociation. When microwave energy is supplied, the cleaning gas dissociates to form uncharged atomic species, for example,  $\text{Cl}_2$  dissociates to form atomic chlorine. When an RF energy is applied to the remote chamber 40, for example, by induction or capacitive coupling, the cleaning gas forms charged ionized species in the remote chamber.

Preferably, the gas activator 175 provides microwaves that chemically activate the cleaning and conditioning gas in the remote chamber by formation of a highly dissociated gas. In this version, as schematically illustrated in Figure 1, the gas activator 175 comprises a microwave waveguide 180 powered by a microwave generator 185, such as the "ASTEX" Microwave Plasma Generator commercially available from the Applied Science & Technology, Inc., Woburn, Massachusetts. Typically, the microwave generator 185 comprises a microwave tuning assembly 190 and a magnetron microwave generator 195 capable of generating microwaves at a frequency of 2.54 Ghz. Typically, the magnetron 195 comprises a high power microwave oscillator in which the potential energy of an electron cloud near a central cathode is converted into microwave energy in a series of cavity resonators spaced radially around the cathode. The resonant frequency of the magnetron 195 is determined by the physical dimensions of the resonator cavities.

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A second gas supply system 200 provides a cleaning gas to the remote chamber 40 via an electronically operated valve 205 and flow control mechanism at a user-selected flow rate. The microwave generator control system then applies power to the microwave generator 185 to generate microwaves which are transported by the waveguide 180 to the remote chamber 40. The activated cleaning gas is transported from the remote chamber 40 to the etching chamber 30 via a gas distribution system comprising the gas conduit 170. Optionally, a filter is positioned in the conduit 170 through which the activated gas species passes before entering the etching chamber 30 to remove particulate matter that is formed during the activation of the reactive species. In the described embodiment, the filter is made of ceramic material having a pore size of about 0.01 to 0.03 microns. Other materials can also be used, such as Teflon (TM DuPont de Nemours, Inc.), polyimide, inactivated carbon, or sulphur. For example, when the cleaning gas comprises  $CF_4$  or  $SF_6$ , or other halogen compounds containing carbon or sulphur, an

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activated carbon of sulphur species is often present as a byproduct of the activation process. It is generally desirable to remove such carbon or sulphur products to prevent contamination of the etching chamber environment.

5                    Instead of using microwaves, the cleaning gas can also be activated by an RF energy provided by a capacitively or inductively coupled source in or adjacent to the remote chamber 40. A suitable RF energy type gas activator comprises an inductor antenna consisting of one or more inductor coils having a circular symmetry with a central axis coincident with the longitudinal  
10 vertical axis that extends through the center of the remote chamber 40, as shown in Figure 4. Alternatively, the gas activator can also comprise a pair of electrodes positioned within the remote chamber 40 to form a capacitively coupled field in the chamber 40, as shown in Figure 3.

15                    The gas distribution system further comprises a gas flow distributor 215 for directing the flow of activated cleaning gas substantially parallel, and adjacent to, one or more internal surfaces of the chamber 30 and a gas flow regulator 220 for regulating the flow of activated cleaning gas into the gas flow distributor 215. The gas flow regulator comprises a flow control valve  
20 205 or 225 operated by a conventional computer control system 230 to control the flow of the cleaning gas into the remote chamber 40 at a predefined or user-selected gas flow rate. Optionally, a carrier gas source can also be connected to the remote activation chamber 40 through another valve and flow control mechanism (not shown). The carrier gas assists in transporting the activated  
25 cleaning gas to the etching chamber 30, and can be any known gas that is non-reactive or compatible with a particular cleaning process. For example, a suitable carrier gas can be argon, nitrogen, helium, halogen, or oxygen. The carrier gas can also assist in the cleaning process by initiating and/or stabilizing the activated gaseous species in the etching chamber 30.

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Preferably, the gas flow distributor 215 directs the flow of the activated cleaning gas generally parallel, or adjacent to, one or more of the surfaces inside the chamber 30, such as the surfaces of the sidewall 45, the bottom surface 50, or the surfaces of components in the chamber. Directing the flow of cleaning gas substantially parallel to certain chamber surfaces provides a more concentrated and laminar flow of cleaning gas adjacent to these surfaces that removes the etch residue and treats and conditions the chamber surfaces more effectively. In the version shown in Figure 3, the gas distributor comprises a plurality of gas injection nozzles 235a, b, c, arranged symmetrically about a central axis of the chamber 30, to provide a laminar curtain of gas flowing immediately past, adjacent, and substantially parallel to the surfaces of the etching chamber 30 to enhance cleaning of the etch residue on the chamber walls. The gas injection nozzles 235a, b, c provide a cleaning gas flow pattern or flow pathway that is directed along the walls and surfaces of the chamber that have a high concentration, thickness, or more chemically hard composition of etch residue, to preferentially clean and condition these surfaces, with excessive erosion of other portions of the chamber that have less etch residue.

In another version, shown in Figure 4, the gas distributor 215 comprises one or more gas injection nozzle 235 that is positioned behind a gas spreading or flow redirecting plate 240 in the chamber 30. The gas spreading plate 240 is symmetrically positioned in the chamber with preferably a perpendicular central axis that is substantially aligned to the central axis of the chamber 30. The plate 240 covers the gas injection nozzle 235 and deflects and redirects the flow of cleaning gas emitted from the injection nozzles 235, between the gap defined by the plate and a parallel portion of the chamber surface adjacent to the plate 240. The gas spreader plate 240 is spaced apart and at a predefined distance from the chamber surface to define a gap having a predefined height. The cleaning gas exits the annular ring-shaped outlet defined by the plate 240 and the chamber surface substantially parallel to the chamber

surface, and flows in a laminar flow path along the surface of the etching chamber walls.

In yet another configuration, illustrated in Figure 5, the gas distributor 215 comprises injection nozzles 235a, b at the terminus of a channel 250 that is symmetrically positioned about a central axis of the chamber 30. An annular ledge 255 is spaced apart from, and preferably covers, at least a portion of the channel 250 to form a circumferential collar that directs the flow of cleaning gas along and past particular surfaces of the chamber 30 to recondition and treat these surfaces. As with the gas plate version illustrated in Figure 4, the annular opening of the channel 250 adjacent to the chamber surfaces, provides a forced flow of cleaning gas past the chamber surfaces.

Preferably, the gas flow distributor 215 comprises gas injection nozzles 235 that are positioned adjacent to surfaces in the chamber 30 that have thicker etch deposit layers, for directing the flow of activated cleaning gas to these regions to preferentially remove the thicker etch residue layers without eroding portions of the chamber 30 having thinner deposit layers. This is particularly useful for etching chambers and processes that produce widely varying composition or thickness of etch residue deposit layers across the surfaces of the chamber 30. Typically, the thicker etch residue regions are adjacent to the substrate, where a larger quantity of resist or mask vaporizes from the substrate, and condenses onto the chamber surfaces. For example, in a preferred configuration, as shown in Figure 6, the gas injection nozzles 235a, b are positioned in a circle that surrounds the substrate 25 and extend from the bottom wall 50 of the chamber 30. This configuration is preferred for etching processes in which a large amount of etch residue is formed near the chamber surfaces that are next to the substrate, because the etch residue is a condensation byproduct of the resist or oxide mask on the substrate. Similarly, the gas injection nozzles 235a, b can be positioned in the other regions of the

chamber 30 as determined from the distribution and etch residue across the chamber surfaces for each type of etch process.

### Etching Process

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Operation of the etching chamber 30 to etch one or more of the silicon-containing layers on the substrate 25 will now be described with reference to the flow chart of Figure 2. The substrate 25 typically comprises a semiconductor material, such as a silicon or gallium arsenide wafer, with a plurality of layers formed thereon. The layers on the substrate 25 comprise, for example, an underlayer of silicon dioxide that functions as a gate oxide layer for MOS transistors, and an overlayer of polysilicon or patterned polycide (which is a combination of tungsten silicide and underlying polysilicon layers). Each of the layers typically have a thickness of about 100 nm to about 350 nm. A mask layer, such as "RISTON" photoresist manufactured by DuPont de Nemours Chemical Company, or an oxide hard mask is applied over the substrate 25 to a thickness of about 0.4 to about 1.3 micron; and the features to be etched in the layers are defined using conventional photolithographic processes. The exposed portions between the mask layer are etched to form features, such as for example, contact holes for fabricating gate electrodes for MOS transistors; polycide interconnecting features that are typically used as gate electrodes; and vias which are multilayer metal structures used to electrically connect two or more electrically conductive layers separated by insulating silicon oxide/nitride layers.

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To perform the process of the present invention, a substrate 25 is transferred using a robot arm 257 from a load-lock transfer chamber through a slit valve and into the chamber 30. A lift finger assembly (not shown) has lift fingers that extend through lift finger openings in the chuck 145 to receive or lift the substrate 25 off the chuck 145. The robot arm 257 places the substrate

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25 on the tips of the lift fingers (not shown) that are elevated by the pneumatic lift mechanism to extend about 2 to 5 centimeters above the surface of the chuck 145. The pneumatic mechanism, under the control of a computer system, lowers the substrate 25 onto the electrostatic chuck 145, and helium is supplied through apertures 265 in the chuck to control the temperature of the substrate 25.

Etchant gas is introduced into the chamber 30 through the gas outlet 85, and the chamber is typically maintained at a pressure ranging from about 0.1 to about 400 mTorr, and more typically from about 0.1 to 80 mTorr. Suitable halogen-containing etchant gases for etching the substrate 25, include for example, HCl, BCl<sub>3</sub>, HBr, Br<sub>2</sub>, Cl<sub>2</sub>, CCl<sub>4</sub>, SiCl<sub>4</sub>, SF<sub>6</sub>, F, NF<sub>3</sub>, HF, CF<sub>3</sub>, CF<sub>4</sub>, CH<sub>3</sub>F, CHF<sub>3</sub>, C<sub>2</sub>H<sub>2</sub>F<sub>2</sub>, C<sub>2</sub>H<sub>4</sub>F<sub>6</sub>, C<sub>2</sub>F<sub>6</sub>, C<sub>3</sub>F<sub>8</sub>, C<sub>4</sub>F<sub>8</sub>, C<sub>2</sub>HF<sub>5</sub>, C<sub>4</sub>F<sub>10</sub>, CF<sub>2</sub>Cl<sub>2</sub>, CFCl<sub>3</sub>, and mixtures thereof. The etching process of the present invention provides high etch rates, and highly selective etching of the silicon layers on the substrate 25. A preferred composition of process gas comprises (i) chlorine, (ii) hydrogen bromide, and optionally (iii) helium-oxygen gas. The chlorine gas is ionized to form atomic chlorine and chlorine-containing species that etch the metal silicide or polysilicon layers to form volatile SiCl<sub>x</sub> species that are exhausted from the chamber 30. The chlorine gas can comprise Cl<sub>2</sub> or other chlorine-containing gases equivalent to chlorine, for example, HCl, BCl<sub>3</sub>, and mixtures thereof. The hydrogen bromide gas enhances the rate of etching of the polysilicon layer while simultaneously reducing the rate of etching of the resist layer to enhance the etching selectivity ratio. The helium-oxygen gas forms excited species and ions that further aid etching rates and etching selectivity.

Referring to Figure 2, a plasma is energized from the etchant gas using the plasma generator 110 by forming an inductive electric field in the chamber 30 and biasing the first and second electrodes 120, 125 in the chamber. The plasma is formed by applying an RF source current to the



inductor antenna 115 encircling the chamber 30 , and applying an RF bias voltage to the electrodes 120, 125. The etchant gas ionizes in the applied electric field to form halogen-containing ions and neutrals that react with the silicon-containing layers on the substrate 25 to etch the layers and form volatile gaseous species that are exhausted from the chamber 30. Preferably, the power ratio  $P_r$  of the source current power level (to inductor antenna 115) to the bias voltage power level (to the process electrodes 120, 125) is selected to enhance the ability of the etchant plasma to anisotropically etch the silicon-containing layers with high selectivity relative to the overlying mask layer.

Increasing the source power level of the current applied to the inductor antenna 115, increases the number of dissociated etchant species in the plasma providing more isotropic etching. In contrast, increasing the bias power level of the RF voltage applied to the process electrodes 120, 125 increases the degree of anisotropic etching by providing a higher bombardment energy component to the plasma ions. It has been discovered that an excessively high power ratio  $P_r$  can cause sputtering of the substrate 25 and result in non-uniform etching of the substrate; while an excessively low power ratio  $P_r$  can cause insufficient dissociation of the etchant gas into dissociated ions resulting in low etch rates and low etching selectivity. A preferred power ratio  $P_r$  is at least about 2:1, and more preferably about 2:1 to about 20:1. The plasma is formed by applying a current at a source power level of about 400 to about 3000 Watts to the inductor antenna 115 encircling the plasma zone 35; and the plasma ions are attracted toward the substrate 25 by applying a voltage at a power level of about 20 to about 1000 Watts to the process electrodes 120, 125 in the plasma zone.

The substrate 25 etching process is typically performed in a main etch stage and an "overetch" stage, in order to stop the etching process without etching through the underlayer on the substrate. The main etch stage is stopped immediately before the overlayer is completely etched through, and

the overetch stage is performed to etch through the residual portion of the overlayer. Typically, the halogen content of the etchant gas is reduced in the overetch stage to obtain slower and more controllable etch rates. For example, a suitable main etch process stage for etching a polysilicon layer an etchant gas comprising 68 sccm  $\text{Cl}_2$ , 112 sccm  $\text{HBr}$ , and 16 sccm  $\text{He-O}_2$  can be used. The power level of the source current applied to the inductor antenna 115 is 475 Watts, and the power level of the bias voltage applied to the process electrodes 120, 125 is 80 Watts to provide a power ratio  $P_r$  of about 6:1. The pressure in the chamber 30 is held at 4 mTorr. A suitable over-etch process stage for the polysilicon layer uses an etchant process gas comprising 158 sccm  $\text{HBr}$  and 10 sccm  $\text{He-O}_2$  at a chamber pressure of 50 mTorr. The power level of the source current applied to the inductor antenna 115 was 1000 Watts, and the power level of the bias voltage applied to the process electrodes 120, 125 was 100 Watts to provide a power ratio,  $P_r$ , of about 10:1, in the overetch process stage.

An optical endpoint measurement technique is used to determine completion of the entire etching process, or completion of etching of a specific layer by measuring the change in light emission of a particular wavelength corresponding to a detectable gaseous species. A sudden decrease or increase in concentration of a selected detectable species, indicates completion of etching of one or more of the layers. For example, a sudden increase in the concentration of silicon species (that results from chemical reaction of the process gas with the underlying polysilicon) indicates completion of the etching process; and an increase in chlorine ion concentration (resulting from reduced erosion of the underlayer) indicates completion of etching of the metal silicide layer and start of etching of the underlayer.

After completion of processing, the pneumatic lifting apparatus 270 raises the lift pins through the electrostatic chuck 145 to raise the substrate 25 and a robotic transport arm is inserted between the substrate 25

and the chuck to lift the substrate off the lift pins. Thereafter, the lift pins are retracted into the chuck 145, and the robotic arm transports the substrate 25 out of the etching chamber 30 and into a transfer chamber maintained in a vacuum environment.

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#### Cleaning & Conditioning Process

Thereafter, a treatment process is used to treat and recondition the surfaces inside the etching chamber 30, particularly the ceramic surfaces; and to clean the etch residue formed on the chamber walls 45, 50, 55 and components. The etch residue adheres and reacts with the surfaces inside the etching chamber 30, for example, the sidewalls 45, receiving surface 140 of the monolithic ceramic member 135, and the ceiling 55 of the chamber, to form a hard and chemically resistant layer that is difficult to remove. The etch residue typically comprise polymeric organic compounds containing halogen, carbon, hydrogen, oxygen, and/or silicon compounds that are formed during etching of the substrate 25. In particular, the etch residues react with the ceramic surfaces in the chamber 30 such as the surfaces of the monolithic ceramic member 135, which have highly reactive surface functional groups. For example, ceramic surfaces comprising silicon or silicon oxide comprise Si-OH<sup>+</sup> surface groups which are formed when the ceramic surface is exposed to air, oxygen, or ambient moisture; and aluminum oxide or aluminum nitride surfaces have Al-OH<sup>+</sup> surface groups. These surface functional groups chemically react with the etch residue to form a hard adherent coating on the chamber surfaces or components.

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The chamber treatment process treats the chamber 30 to remove and reduce the adverse effect of the reaction byproducts of the etch residues and the chamber surfaces will now be described. To perform the process, the process chamber 30 is exhausted of etchant gas by fully opening the throttle

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valve 95 of the exhaust system 90. Cleaning gas, such as  $\text{NF}_3$ ,  $\text{CF}_4$ ,  $\text{SF}_6$ ,  $\text{C}_2\text{F}_6$ ,  $\text{CCl}_4$ ,  $\text{C}_2\text{Cl}_6$  or mixtures thereof, is introduced into the remote chamber 40 and activated therein, for example, by microwaves applied within the remote chamber by the microwave generator 185, or by RF energy applied via electrodes or an inductor coil. Thereafter, the activated cleaning gas is introduced into the etching chamber 30 to clean the etch residue in the chamber.

The power level  $P_L$  of the current used to operate the gas activator 175 is selected to achieve two functions. In a first function, the cleaning gas should chemically react with and vaporize the thin layer of etch residue comprising polymer containing carbon, trapped halogen species, silicon, and/or hydrogen species, formed on the chamber surfaces. The flow rate  $F_R$  of cleaning gas, and the power level  $P_L$  of the gas activator 175 control the ratio of dissociated to non-dissociated species in the activated cleaning gas. The more highly dissociated gaseous species preferentially react with the thin etchant layer relative to the underlying chamber surfaces. That is why the activated plasma can remove thin layers of etch residue on the chamber walls, while minimizing erosion of the underlying chamber surfaces. In a second function, the activated cleaning gas reconditions the surfaces in the chamber 30, particularly the ceramic surfaces, after removing the etch residue. It has been discovered that halogen containing etch residue is highly chemical reactivity to the chamber walls 45, 50, 55 and components, particularly when the etching chamber 30 contains ceramic surfaces that have highly reactive surface functional groups, such as the aforementioned  $\text{Si-OH}^+$ ,  $\text{Al-OH}^+$ , and other such species. For example, fluorine containing species in the etch residue rapidly erode ceramic aluminum oxide or nitride surfaces to form volatile  $\text{AlF}_3$  species. Similarly, bromine containing species hydrolyze in ambient moisture to form acidic hydrogen bromide which corrodes silicon-containing components. These types of etch residues need to be rapidly removed from the chamber 30 to

prevent excessive erosion of the chamber surfaces. A high flow rate  $F_R$  and low power level  $P_L$  activated gas species conditions the chamber surfaces, i.e., restores at least a portion of the surface functional groups, such as AlOH groups, on the ceramic surfaces in the chamber 30. This returns the chamber surfaces to a chemical state similar to their original chemical state, thereby restoring their pristine surface activity and surface functionality, for the next etching process. As a result, the etching processes performed in the treated chamber 30 yield more reproducible results, as compared to chambers where a wet cleaning or an RIE cleaning process is used to clean the chamber.

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Preferably, the flow rate  $F_R$  of the cleaning gas and the power level  $P_L$  of the current applied to the gas activator 175, such as the microwave plasma generator 185, are selected to vaporize the etch residue on the etching chamber surfaces to a sufficiently low concentration to remove their effect on the chamber gas composition and substrate contamination, without eroding the walls or components in the chamber 30. The flow rate  $F_R$  of the cleaning gas should be sufficiently high to react with substantially all the etch residue on the ceramic surfaces to form gaseous byproducts. However, excessively high flow rates can cause erosion of the chamber walls and surfaces by the extended exposure to the highly activated gaseous species in the cleaning gas.

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For example, it has been discovered that when etching silicon-containing layers on the substrate 25, a relatively thin etch residue containing primarily polymeric and silicon-containing species, and having a thickness of about 0.01 to about 1000 microns is formed on the chamber walls 45, 50, 55 and surfaces. This etch residue layer is removed by introducing into the chamber 30, an activated cleaning gas at a flow rate  $F_R$  equivalent to a rate of about 200 to about 2000 sccm for a chamber having a volume of about 40,000  $\text{cm}^3$  for a time period of about 0.5 to 100 seconds to clean the etch residue, substantially without eroding the walls and components in the chamber. For

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different sized process chambers, equivalent flow rates of cleaning gas compositions that maintain substantially the same ratio of  $\text{NF}_3$  flow in sccm to chamber volume in  $\text{cm}^3$  should be used. While process gas consisting only of  $\text{NF}_3$  provides good results, inert gases such as helium or argon can also be added to the process gas, or the process gas can comprise a commercially available mixture of gases, such as  $\text{He-O}_2$ .

When a gas activator 175 which comprises a microwave generator 185 is used, the power level  $P_L$  operating the microwave generator 185, which is also a measure of the power or intensity of microwaves applied to the remote plasma chamber 40 via the gas activator 175, is selected to clean and treat the chamber 30 surfaces without eroding the chamber walls. The power level should be sufficiently high to provide a cleaning gas that is sufficiently reactive to remove substantially all the etch residue on the chamber walls and components without damage to the underlying structures. An excessively high power level  $P_L$  will cause the highly activated gaseous species to erode the chamber walls. Conversely, a cleaning gas activated at a power level that is too low, will fail to remove the thick chemically hard etch residue on portions of the chamber walls and components. Suitable power levels for the  $\text{NF}_3$  cleaning gas are from about 500 to about 4000 watts, and more preferably, from about 1500 to about 2500.

The activated gaseous species are introduced into the etching chamber 30 for a short burst of time to treat and condition the chamber. The short burst of activated cleaning gas provides significant advantages over conventional cleaning processes. First, the burst of activated cleaning gas provides a larger number of highly dissociated species that removes the etch residues, and cleans and conditions the ceramic surfaces in the chamber 30 by a "soft" chemically reactive process performed by the highly chemically reactive dissociated species. The burst and quick removal of the cleaning gas from the

chamber 30 also reduces the possibility of dissociated species from recombining to form other chemical species that erode the chamber surfaces and components. This mechanism is further aided by the high flow rates of the burst of gas which assist in flushing out the reaction byproducts before they recombine in the chamber 30. Also, the burst of gas maintains a fresh supply of cleaning gas at the exposed surfaces of the etch residue during the cleaning operation thereby removing the residue layers at a fast rate. Preferably, the burst of activated cleaning gas is introduced into the etching chamber at a flow rate  $F_R$  equivalent to a rate of at least about 200 to about 2000 sccm for an etching chamber 30 having a volume of about 40,000 cm<sup>3</sup> for a time period of about 0.5 to about 100 seconds to clean the etch residue, substantially without eroding the walls and components in the chamber. More preferably, the remotely generated cleaning gas is introduced into the etching chamber for about 0.5 to about 24 seconds.

In another aspect of the present invention, useful for reducing equipment down time and increasing throughput of the etching chamber 30, the cleaning process is performed while transporting the substrate 25 out of the chamber, or immediately after the substrate 25 is removed from the etching chamber 30. In this version, activated cleaning gas is prepared in the remote chamber 40, and while simultaneously transporting the substrate 25 out of the etching chamber 30, a burst of high flow rate  $F_R$  of activated cleaning gas is introduced into the etching chamber 30 for a time period sufficient to treat and condition the surfaces of the etching chamber 30 substantially without eroding the surfaces. For example, as the substrate 25 is finishing etching, the cleaning gas is introduced into the remote chamber 40 by opening an inlet valve 205 in the gas line between the cleaning gas supply 200 and the remote chamber 40; and the activated cleaning gas is allowed to flow into the etching chamber 30 while the substrate is being removed from the etching chamber 30. Inlet valve 205 of the remote chamber is in a closed position during etching of the

substrate, and as the etched substrate 25 is being removed or transported from the etching chamber 30, for example, while the substrate 25 is passing through the slit valve at the sidewall 45 of the etching chamber, a robot controller 259 sends a first signal that opens the inlet valve 205 to allow cleaning gas to enter into the remote chamber 40. For example, the robot controller 259 can provide a first trigger signal to the computer control system 230 that in response opens the inlet valve 205 and actuates the microwave generator 185, forming activated cleaning gas. The cleaning gas flows into the etching chamber 30 for a short time period to clean and condition the surfaces in the chamber 30. The robot controller 259 then provides a second trigger signal that closes the inlet valve 205 when a second substrate 25 is retrieved for insertion into the etching chamber 30 and allows the exhaust system 90 to exhaust residual activated gas from the etching chamber. Thereafter, another substrate 25 is transported into the chamber 30 and the etching, transportation, and chamber cleaning and conditioning steps are repeated, until all substrates 25 supply have been processed. In this method, the etching process stages are not delayed or slowed down by the cleaning process stages, thereby providing improved processing throughput.

In yet another version, an outlet valve 225 from the remote chamber is in a closed position during activation of the cleaning gas. As the etched substrate 25 is removed or transported from the etching chamber 30, the robot controller 259 sends a first signal that opens the outlet valve 225 in the gas conduit 170 allowing activated cleaning gas to flow into the etching chamber 30 for a short time period to clean and condition the surfaces in the chamber. The robot controller 259 then provides a second trigger signal that closes the outlet valve 225 when a second substrate 25 is retrieved for insertion into the etching chamber 30. Thereafter, another substrate 25 is transported into the chamber 30 and the etching, transportation, and chamber cleaning and conditioning steps are repeated.



In yet another aspect of the present invention, a lower pressure of gas is maintained in the etching chamber 30 relative to the pressure in the remote chamber 40. This aspect of the present invention can be used in conjunction with the specialized gas distributor structures described above to  
5 direct the flow of cleaning gas adjacent to particular chamber surfaces that need to be cleaned more vigorously, for example, by providing the cleaning gas injection nozzles 235 adjacent to, or facing the portions of chamber having thicker etchant residues. It is believed that a more rapid flow of activated cleaning gas enters into the process chamber because of the differential  
10 pressure maintained between the two chambers, causing the cleaning gas to rapidly impinge against and clean the chamber surfaces. In this process, the interior volume of the etching chamber 30 is maintained at a higher pressure than the remote chamber 40. In this method, the etching chamber 30 is preferably maintained at a lower pressure than the remote chamber 40. The  
15 etching chamber 30 is preferably maintained at a pressure of 0.1 to 80 mTorr, and the remote chamber 40 is maintained at a pressure of about 500 to about 3000 mTorr.

In another preferred aspect of the invention, useful for cleaning  
20 and conditioning chamber surfaces that are highly reactive to the etch residue, such as the ceramic surfaces, a multicycle cleaning process is used to treat chamber surfaces and reduce the concentration of etch residue. In a first stage, a first activated cleaning gas is formed by maintaining the gas activator 175, such as the microwave generator 185, at a first power level. In at least one  
25 second stage, a second activated cleaning gas is formed by maintaining the gas activator 175 at a second power level that is lower than the first power level. The cleaning gas activated by the first higher power level of the first cleaning stage provides a more dissociated and chemically reactive species that removes the hard and thick etch residues on portions of the chamber walls 45, 50, 55  
30 and components that are near the substrate 25. The cleaning gas in the second

cleaning stage is activated at a lower power level to efficiently treat and condition surfaces such as the ceramic surfaces, to provide optimal etching conditions in the chamber 30. Preferably, the first power level is at least about 500 watts, and more preferably from about 500 to about 3000 watts; and the  
5 second power level is at least about 1000 watts, and more preferably about 1500 to about 4000 watts. The multiple power level process is repeated a sufficient number of times to treat the chamber walls to reduce the concentration of etch residue in the chamber 30 to the desirable level, typically from a single cycle, to a range of about 1 to about 10 cycles. The duration of  
10 each cleaning stage is from about 0.5 to about 100 seconds, and more preferably, from about 2 to about 30 seconds.

The chamber treatment process of the present invention is advantageous because it maximizes the chemical reactivity of the activated  
15 cleaning gas to the etch residues in the chamber 30, and minimizes the chemical reactivity of the cleaning gas to the exposed surfaces in the etching chamber 30. The cleaning process has been found to uniformly remove etch residues, irrespective of their thickness or chemical stoichiometry. Prior art cleaning processes, particularly those performed by an operator, often fail to uniformly  
20 clean and remove the etch residue deposits formed on chamber surfaces. Build-up of etchant deposits on the chamber surfaces, result in flaking off the etchant deposits and contamination of the substrate 25 etched in the chamber. By uniformly removing the etch residues formed across substantially all of the chamber surfaces, such contamination and reduced yields from the substrate  
25 25, are minimized.

The activated cleaning gas also results in far less erosive damage to the chamber compared to conventional in-situ plasma cleaning steps, because of the reduced energy levels of the plasma in the etching chamber. This was  
30 difficult to accomplish in prior art processes, in which the high powered plasmas

used to remove the residue deposits also resulted in extensive erosion of chamber surfaces and components. By reducing the need to replace chamber components, the cost of operating the etching chamber 30 and the cost per substrate 25 are significantly reduced. Furthermore, the activated cleaning gas  
5 can be used to efficiently clean an etch chamber 30 in-situ during etching of substrates 25, and preferably during transport of the substrates between the etching chamber 30 and the loading chamber, rather than stopping processing in the chamber 30 to wet clean the chamber walls and components, thereby increasing etching throughput and further reducing costs per substrate. The  
10 cleaning process is expected to increase chamber lifetimes by a factor of at least 2, and also increase substrate yields by reducing the deposition of flaked-off etchant byproducts onto the substrate.

The treatment and cleaning process removes chemically-adhered  
15 etchant deposits from active surfaces in the chamber 30, and restores the original chemical reactivity and surface functional groups of these surfaces. The cleaning and treatment process is also particularly useful for cleaning etch residue that is strongly adhered to, or chemically reacted with ceramic surfaces, such as surfaces comprising one or more of aluminum nitride, boron carbide,  
20 boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide. The activated cleaning gas is effective at treating and reconditioning these ceramic surfaces to provide surface chemistries and surface functional groups that are chemically compatible with the etching process. The conditioned ceramic surfaces provide  
25 more reproducible etching properties in the chamber 30, than that provided by alternative chamber cleaning processes, such as wet cleaning or RIE cleaning processes. The significantly improved reproducibility of etching processes performed in the chamber 30 is highly desirable.

The present invention has been described with reference to certain preferred versions thereof; however, other versions are possible. For example, the treatment and cleaning process of the present invention can be used for treating chambers for other applications, as would be apparent to one of  
5 ordinary skill. For example, the process can be applied, as would be apparent to one of ordinary skill in the art, to treat sputtering chambers, ion implantation chambers, or deposition chambers, or in combination with other cleaning processes. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

**What is claimed is:**

1. A method of cleaning an etch residue from walls and components of an etching chamber, the method comprising the steps of:
  - 5 (a) introducing a cleaning gas into a remote chamber adjacent to the etching chamber;
  - (b) activating the cleaning gas inside the remote chamber to form an activated cleaning gas; and
  - (c) introducing the activated cleaning gas into the  
10 etching chamber to clean the etch residue on the walls and components of the etching chamber.
2. A method according to claim 1 wherein the etch residue comprises a layer containing polymeric and silicon-containing species, and  
15 having a thickness of about 0.01 to about 1 micron, and  
wherein the activated cleaning gas is introduced into the etching chamber at a flow rate  $F_R$  equivalent to a rate of about 200 to about 2000 sccm for a chamber having a volume of about 40,000 cm<sup>3</sup> for a time period of about 0.5 to about 100 seconds.  
20
3. A method according to claim 1 wherein the activated cleaning gas is introduced into the etching chamber for about 0.5 to about 24 seconds.
- 25 4. A method according to claim 2 wherein the cleaning gas is activated by microwaves applied in the remote chamber by a microwave plasma generator operated at a power level of about 500 to about 4000 Watts.
- 30 5. A method according to claim 1 wherein the etching chamber is maintained at a lower pressure than the remote chamber.

6. A method according to claim 8 wherein the etching chamber is maintained at a pressure of about 0.1 to about 80 mTorr, and the remote chamber is maintained at a pressure of about 500 to about 3000 mTorr.

5 7. A method according to claim 1 wherein the cleaning gas is selected from the group consisting of  $\text{NF}_3$ ,  $\text{CF}_4$ ,  $\text{SF}_6$ ,  $\text{C}_2\text{F}_6$ ,  $\text{CCl}_4$ ,  $\text{C}_2\text{Cl}_6$ , and mixtures thereof.

10 8. A method according to claim 1 wherein the surfaces in the etching chamber comprise one or more of aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide.

15 9. A method according to claim 1 comprising the initial step of etching silicon-containing layers on a substrate in the etching chamber, by the steps of:

(a) introducing process gas comprising silicon etching gas into the etching chamber; and

20 (b) forming an etching plasma from the process gas by applying RF current at a source power level to an inductor coil adjacent to the chamber, and applying a RF voltage at a bias power level to process electrodes in the chamber, wherein the power ratio  $P_r$  of the source power level to the bias power level is less than about 20:1, thereby rapidly etching the silicon-containing layer with reduced formation of etch residue on the walls and  
25 components of the chamber.

10. A method of etching a substrate, and treating and conditioning surfaces of walls and components in an etching chamber, the method comprising the steps of:

5 (a) etching the substrate in the etching chamber thereby depositing etch residue on the surfaces of the walls and components in the etching chamber; and

10 (b) simultaneously transporting the substrate out of the chamber, while introducing a burst of high flow rate  $F_R$  of activated cleaning gas into the etching chamber for a time period sufficient to treat and condition the surfaces of the etching chamber substantially without eroding the surfaces.

11. A method according to claim 10 wherein in step (b) the activated cleaning gas is introduced into the etching chamber at a flow rate  $F_R$  equivalent to a rate of about 200 to about 2000 sccm for a chamber having a  
15 volume of about 40,000 cm<sup>3</sup> for a time period of about 0.5 to about 100 seconds.

12. A method according to claim 11 wherein the activated cleaning gas is introduced into the etching chamber for about 0.5 to about 24  
20 seconds.

13. A method according to claim 10 wherein the cleaning gas is activated by microwaves applied in the remote chamber by a microwave plasma generator operated at a power level of about 500 to about 4000 Watts.  
25

14. A method according to claim 1 wherein the etching chamber is maintained at a higher pressure than the remote chamber.

15. A method according to claim 14 wherein the etching chamber is maintained at a pressure of about 0.1 to about 80 mTorr, and the remote chamber is maintained at a pressure of about 500 to about 3000 mTorr.

5 16. A method according to claim 11 wherein the surfaces in the etching chamber comprise one or more of aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide.

10 17. A method for treating an etching chamber to remove an etch residue from walls and components of the etching chamber, the method comprising the steps of introducing a burst of activated cleaning gas into the etching chamber at a flow rate  $F_R$  equivalent to a rate of at least about 200 to about 2000 sccm for an etching chamber having a volume of about 40,000 cm<sup>3</sup>  
15 for a time period of about 0.5 to about 100 seconds to clean the etch residue, substantially without eroding the walls and components in the chamber.

20 18. A method according to claim 17 wherein the activated cleaning gas is introduced into the etching chamber for about 0.5 to about 24 seconds.

25 19. A method according to claim 17 wherein the cleaning gas is activated by microwaves applied in the remote chamber by a microwave plasma generator operated at a power level of about 500 to about 4000 Watts.

20. A method according to claim 17 wherein the etching chamber is maintained at a higher pressure than the remote chamber.



21. A method according to claim 20 wherein the etching chamber is maintained at a pressure of about 0.1 to about 80 mTorr, and the remote chamber is maintained at a pressure of about 500 to about 3000 mTorr.

5           22. A method according to claim 17 wherein the surfaces in the etching chamber comprise one or more of aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide.

10           23. A method for treating an etching chamber to remove an etch residue from walls and components of the etching chamber, the method comprising the steps of:

                  (a) a first stage, in which a first activated cleaning gas formed by maintaining the gas activator in the remote chamber at a first power level, is introduced into the etching chamber;

15

                  (b) at least one second stage, in which a second activated cleaning gas formed by maintaining the gas activator in the remote chamber at a second power level different from the first power level, is introduced into the etching chamber.

20

24. A method according to claim 23 wherein the first and second stages are each performed for about 0.5 to about 100 seconds.

25           25. A method according to claim 23 wherein in the first stage, the power level applied to the microwave generator is at least about 2000 watts, and wherein in the second stage, the power level applied to the microwave generator is at less than about 1000 watts.

26. A method according to claim 23 wherein in one or both of the stages, the activated cleaning gas is introduced into the etching chamber at a flow rate  $F_R$  equivalent to a rate of about 200 to about 2000 sccm for a chamber having a volume of about 40,000 cm<sup>3</sup>.

5

27. A method according to claim 23 wherein the etching chamber is maintained at a pressure of about 0.1 to about 80 mTorr, and the remote chamber is maintained at a pressure of about 500 to about 3000 mTorr.

10

28. A method according to claim 23 wherein the surfaces in the etching chamber comprise one or more of aluminum nitride, boron carbide, boron nitride, diamond, silicon oxide, silicon carbide, silicon nitride, titanium oxide, titanium carbide, yttrium oxide, and zirconium oxide.

15

29. An apparatus for etching a substrate, the apparatus comprising:

(a) an etching chamber having a process gas inlet for introducing process gas into the chamber, a plasma generator for forming a plasma from the process gas for etching a substrate, and an exhaust system for exhausting the spent process gas from the etching chamber;

20

(b) a remote chamber adjacent to the etching chamber for forming an activated cleaning gas therein;

(c) a gas distribution system comprising (i) a gas conduit for transporting the activated cleaning gas from the remote chamber to the etching chamber, (ii) a gas flow distributor for directing the flow of activated cleaning gas substantially parallel, and adjacent to, one or more internal surfaces of the chamber, and (iii) a gas flow regulator for regulating the flow of activated cleaning gas into the gas flow distributor.

25

30. The apparatus of claim 29 wherein the gas flow distributor comprises a plurality of gas injection nozzles positioned in the etching chamber to be adjacent to the portions of the surfaces in the chamber that have thicker etch residue layers.

5

31. The apparatus of claim 29 wherein the gas flow distributor comprises a plurality of gas injection nozzles arranged symmetrically about a central axis of the chamber.

10

32. The apparatus of claim 29 wherein the gas flow injection nozzles are positioned behind a plate parallel to a surface of the chamber.

15

33. The apparatus of claim 29 wherein the gas flow distributor comprises one or more gas injection nozzles terminating in a channel in the chamber, the channel comprising an extended annular ledge covering at least a portion of the channel.

20

34. A method of using the apparatus of claim 29 to etch a substrate, the method comprising the steps of:

- (1) etching the substrate in the etching chamber;
- (2) removing the substrate from the chamber; and
- (3) during or after step (2), cleaning and conditioning the chamber by introducing activated cleaning gas into the etching chamber using the gas flow distribution system.

25

35. An apparatus for etching a substrate, the apparatus comprising:

- (a) an etching chamber having a process gas inlet for introducing process gas into the chamber, a plasma generator for forming a

plasma from the process gas for etching a substrate, and an exhaust system for exhausting the spent process gas from the etching chamber;

(b) a remote chamber adjacent to the etching chamber for forming an activated cleaning gas therein;

5 (c) a gas distribution system comprising (i) a gas conduit for transporting the activated cleaning gas from the remote chamber to the etching chamber, (ii) a gas flow distributor having nozzles positioned adjacent to a surfaces in the chamber that have thicker etch deposit layers, for directing the flow of activated cleaning gas to these regions to preferentially remove the  
10 thicker etch deposit layers without eroding portions of the chamber having thinner deposit layers.

36. The apparatus of claim 35 wherein the gas flow distributor comprises a plurality of gas injection nozzles arranged symmetrically about a  
15 central axis of the chamber.

37. The apparatus of claim 35 wherein the gas flow injection nozzles are positioned behind a plate parallel to a surface of the chamber.

20 38. The apparatus of claim 35 wherein the gas flow distributor comprises one or more gas injection nozzles terminating in a channel in the chamber, the channel comprising an extended annular ledge covering at least a portion of the channel.

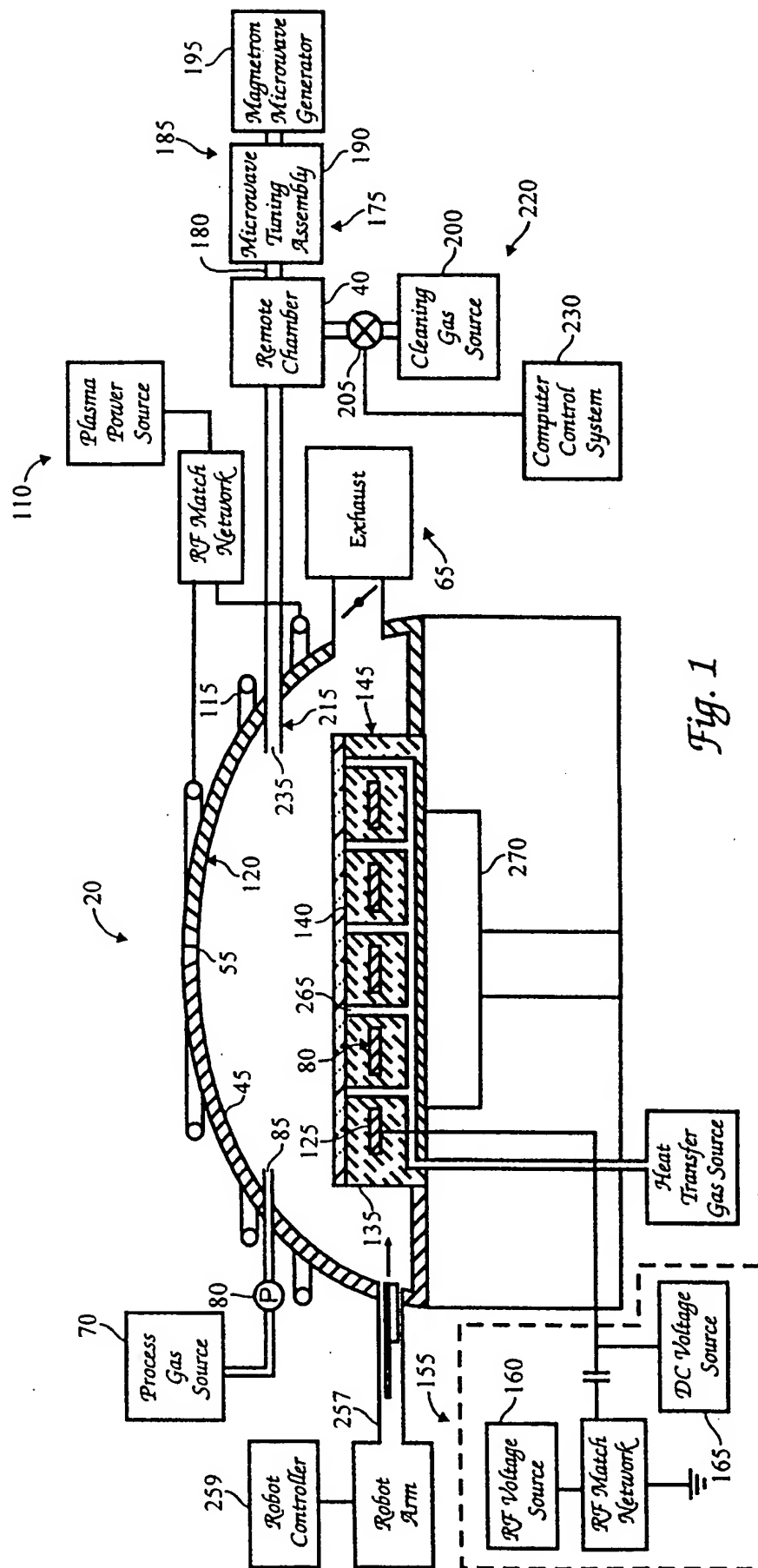
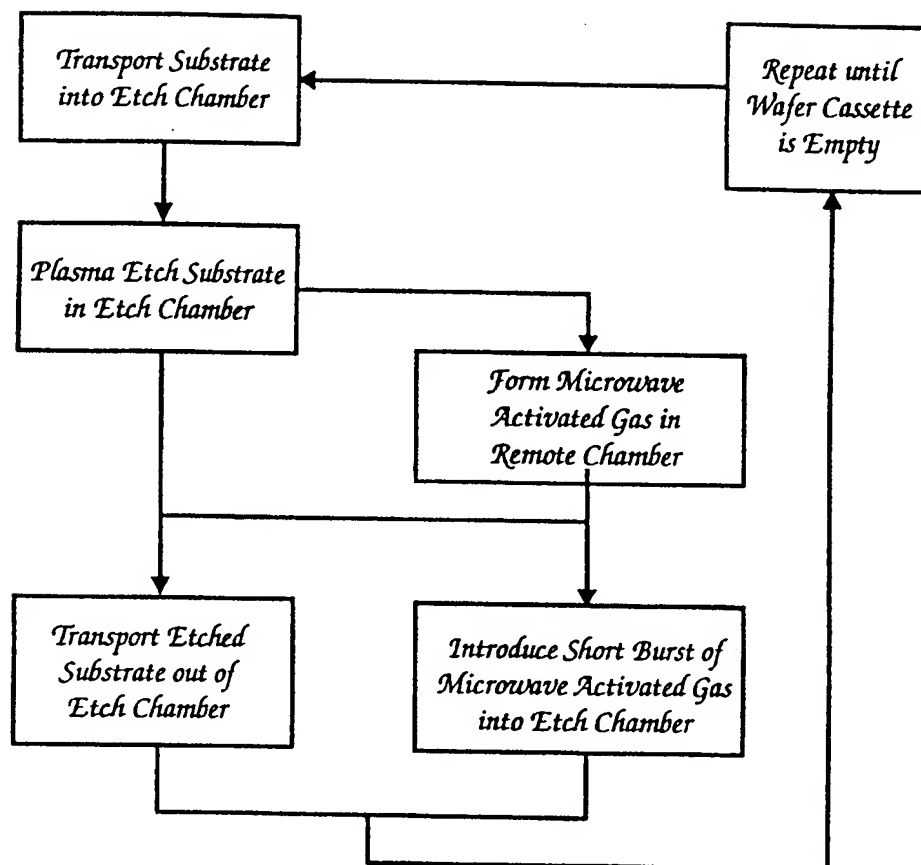


Fig. 1

*Fig. 2*

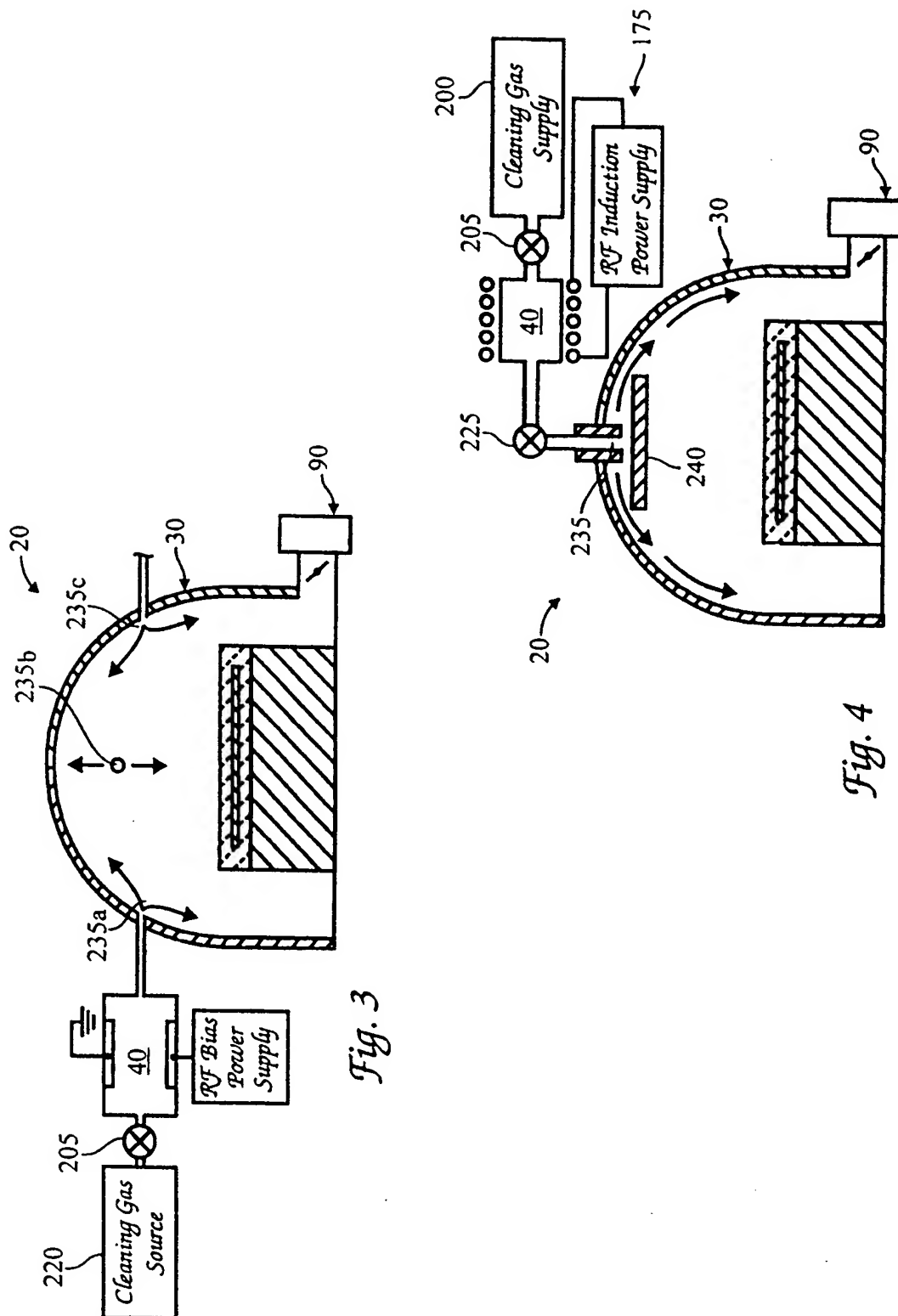
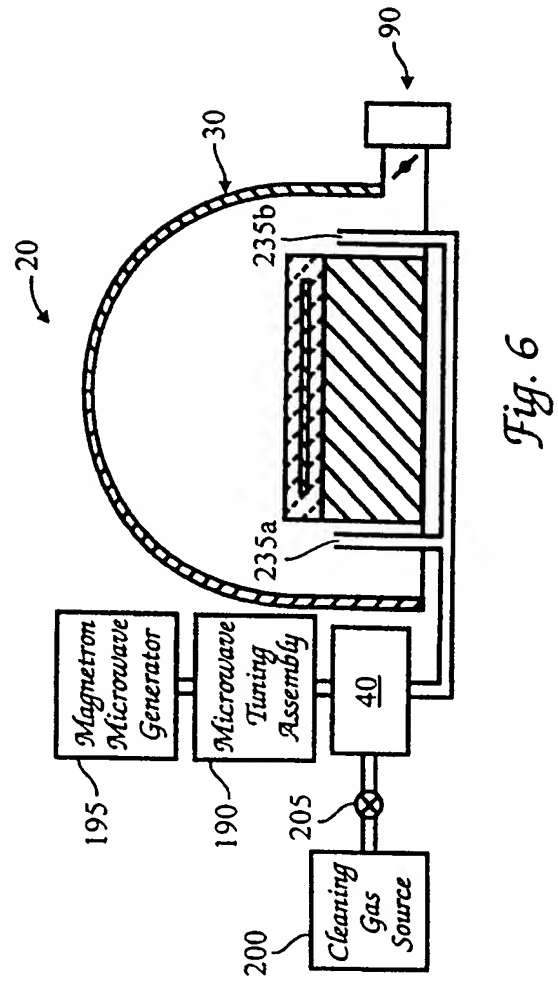
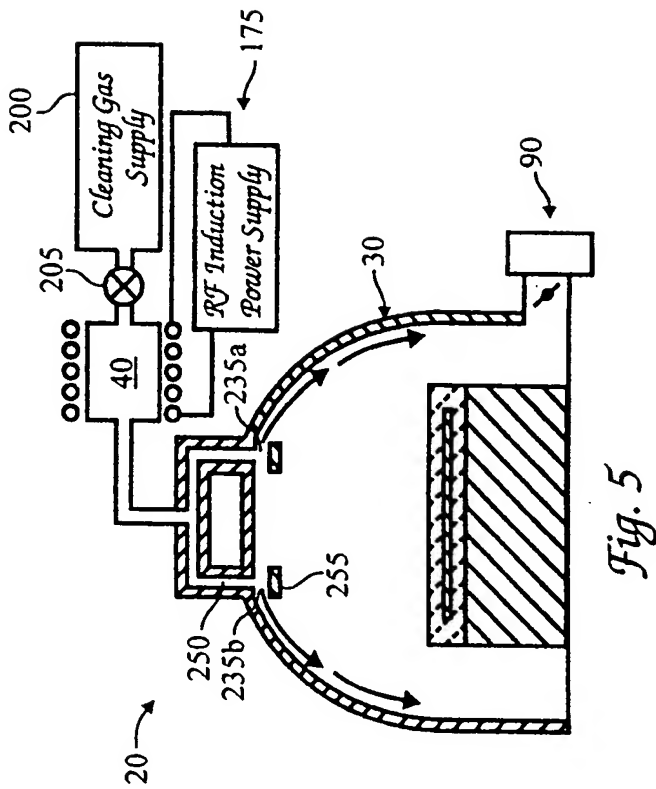


Fig. 3

Fig. 4





## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/21806

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 C23C16/44

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C23C H01J B08B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 224 (E-525), 21 July 1987 & JP 62 040728 A (TOKUDA SEISAKUSHO LTD; OTHERS: 01), 21 February 1987	1, 5, 10, 14
Y	see abstract	34
X	US 5 389 197 A (ISHIMARU YASUSHI) 14 February 1995	29, 35
Y	see column 4, line 48 - column 5, line 30; figure 2	34
A	US 5 637 237 A (OEHRLEIN GOTTLIEB S ET AL) 10 June 1997 see column 5, line 38 - line 44	8, 16, 22
A	EP 0 697 467 A (APPLIED MATERIALS INC) 21 February 1996 see claims 1-23	1-38
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&amp;" document member of the same patent family

Date of the actual completion of the international search

12 February 1999

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/21806

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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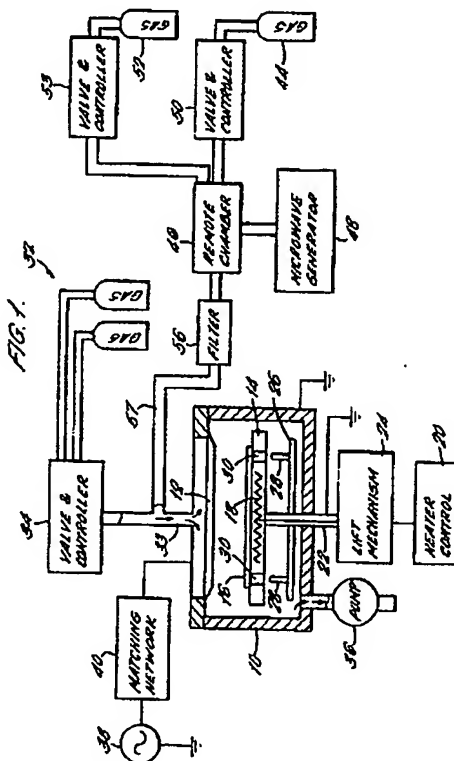
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**(54) Method and apparatus for cleaning a deposition chamber**

(57) A method for cleaning a deposition chamber (10) that is used in fabricating electronic devices including the steps of delivering a precursor gas into a remote chamber (46) that is outside the deposition chamber, activating the precursor gas in the remote chamber using a microwave generator (48) to form a reactive species, flowing the reactive species from the remote chamber into the deposition chamber via conduit (57), and using the reactive species that is flowed into the deposition chamber from the remote chamber to clean the inside of the deposition chamber.



## APPENDIX B

Appl. No.: 10/759,953

## Description

Plasma assisted chemical reactions have been widely used in the semiconductor and flat panel display industries. One example is plasma-enhanced chemical vapor deposition (PECVD), which is a process that is used in the manufacture of thin film transistors (TFT) for active-matrix liquid crystal displays (AMLCDs). In accordance with PECVD, a substrate is placed in a vacuum deposition chamber that is equipped with a pair of parallel plate electrodes. One of the electrodes, e.g. the lower electrode, generally referred to as a susceptor, holds the substrate. The other electrode, i.e., the upper electrode, functions as a gas inlet manifold or shower head. During deposition, a reactant gas flows into the chamber through the upper electrode and a radio frequency (RF) voltage is applied between the electrodes to produce a plasma within the reactant gas. The plasma causes the reactant gas to decompose and deposit a layer of material onto the surface of the substrate.

Though such systems are designed to preferentially deposit the material onto the surface of the substrate, they also deposit some material onto other interior surfaces within the chamber. Consequently, after repeated use, these systems must be cleaned to remove the deposited layer of material that has built up in the chamber. To clean the chamber and the exposed components within the chamber, an in-situ dry cleaning process is commonly used. According to the in-situ technique, precursor gases are supplied to the chamber. Then, by locally applying a glow discharge plasma to the precursor gases within the chamber, reactive species are generated. The reactive species clean the chamber surfaces by forming volatile compounds with the process deposit on those surfaces.

This in-situ cleaning technique has several disadvantages. First, it is inefficient to use a plasma within the chamber to generate the reactive species. Thus, it is necessary to use relatively high powers to achieve an acceptable cleaning rate. The high power levels, however, tend to produce damage to the hardware inside of the chamber thereby significantly shortening its useful life. Since the replacement of the damaged hardware can be quite costly, this can significantly increase up the per substrate cost of product that is processed using the deposition system. In the current, highly competitive semiconductor fabrication industry where per substrate costs are critical to the cost conscious purchasers, the increased operating costs resulting from having to periodically replace parts that are damaged during the cleaning process is very undesirable.

Another problem with the conventional in-situ dry cleaning processes is that the high power levels that are required to achieve acceptable cleaning rates also tend to generate residues or byproducts that can damage other system components or which cannot be removed except by physically wiping off the internal surfaces of the chamber. For example, in a  $\text{Si}_3\text{N}_4$  deposition system

which uses  $\text{NF}_3$  for cleaning,  $\text{N}_x\text{H}_y\text{F}_z$  compounds tend to be generated. These ammonium compounds deposit in the vacuum pump where they can negatively affect the reliability of the pump. As another example, in a deposition system in which the chamber or the process kit components (e.g. heater, shower head, clamping rings, etc.) are made of aluminum, an  $\text{NF}_3$  plasma is often used to clean the interior surfaces. During the cleaning process, a certain amount of  $\text{Al}_x\text{F}_y$  is formed. The amount that is formed is greatly increased by the ion bombardment that results from the high plasma energy levels. Thus, a considerable amount of  $\text{Al}_x\text{F}_y$  can be formed in the system. Unfortunately, this material cannot be etched away by any known chemical process, so it must be removed by physically wiping the surfaces.

In accordance with the present invention, a remote excitation source is used outside of the process chamber to generate a reactive species which is then supplied to the process chamber to assist in carrying out a particular process, e.g. dry cleaning the chamber. In the case of the dry cleaning process, the remote excitation source breaks down the feed gas (e.g. a compound of chlorine or fluorine) to form a long lived halogen species. A second local excitation source may then optionally be used inside the chamber to sustain the long lived species and/or to further break down the gas to form the reactive species. Since the remote excitation source is relied upon to generate the reactive species, the local excitation source may be operated at much lower power levels than are required in a conventional systems. Thus, by moving the excitation source outside of the chamber, high plasma power levels are no longer needed inside the chamber to achieve acceptable cleaning rates. Indeed, in some cases it may not even be necessary to use any local excitation source (e.g. plasma) within the chamber.

In general, in one aspect, the invention is a method for cleaning a deposition chamber that is used in fabricating electronic devices. The method includes the following steps: delivering a precursor gas into a remote chamber that is separate from the deposition chamber; activating the precursor gas in the remote chamber to form a reactive species; flowing the reactive species from the remote chamber into the deposition chamber; and using the reactive species that is flowed into the deposition chamber from the remote chamber to clean the inside of the deposition chamber.

In general, in another aspect, the invention is a method of performing a process to fabricate electronic devices within a process chamber. The method includes the steps of: delivering a precursor gas into a remote chamber that is separate from the process chamber; activating the precursor gas in the remote chamber to form a reactive species; flowing the reactive species from the remote chamber into the process chamber; using a local activation source to further excite the reactive species that has been flowed into the process chamber from the remote chamber; and using the reactive species that has

been further excited by the local activation source in performing the fabrication process in the process chamber.

In general, in yet another aspect, the invention is a deposition apparatus that can be connected to a source of precursor gas for cleaning. The apparatus includes a deposition chamber, a first activation source adapted to deliver energy into the deposition chamber, a remote chamber that is separate from the deposition chamber, a second activation source separate from the first activation source and adapted to deliver energy into the remote chamber, a first conduit for flowing a precursor gas from a remote gas supply into the remote chamber where it is activated by the second activation source to form a reactive species, and a second conduit for flowing the reactive species from the remote chamber into the deposition chamber.

Technically, the remote plasma is used to generate reactive species. To help solve the problem of quenching of the reactive species while its flowing to the chamber a mild plasma may be applied in the process chamber to assist the cleaning. The use of the combined plasma sources achieves a better cleaning rate than would be associated with using either a local or a remote plasma alone. In addition, because of the invention permits the use of a low energy plasma (or even no plasma) within the deposition chamber, much less damage is done to the internal chamber components as a result of the cleaning process and there is much less formation of particulates and undesirable byproducts, such as  $Al_2F_6$ , the disadvantages of which were described above. In addition, in embodiments which use both remote and local excitation sources, each source can be independently adjusted to achieve optimum results. Moreover, in the case that a local plasma is not available in the system, some other activation techniques may be applied (such as thermal excitation).

A further advantage of the invention is that unwanted byproducts that are formed when activating the reactive species can easily be filtered out before the reactive species enters the deposition chamber. In addition, use of the local source to sustain the activated species lessens the restrictions that might exist on the placement of the remote activation chamber. That is, the remote activation chamber can be placed conveniently, even at further distances from the deposition chamber, with less concern about quenching of the activated species as it is being transferred from the remote chamber to the deposition chamber. This means that it will be relatively easy to retrofit existing systems with this capability.

Using the combination of remote and local excitation sources has the further advantage that it can be applied to a wide variety of applications and systems with similar benefits. For example, it can also be used in PVD and CVD systems, plasma etching systems, and systems for cleaning substrates, ion doping, and stripping of photoresist.

Other advantages and features will become apparent from the following description of the preferred em-

bodiment and from the claims.

Fig. 1 shows a block diagram of a PECVD system which embodies the invention.

In the described embodiment, we used a model AKT-1600 PECVD System manufactured by Applied Kometech Technology, modified as described herein. The AKT-1600 PECVD is designed for use in the production of active-matrix liquid crystal displays (AMLCDs). It is a modular system with multiple process chambers which can be used for depositing amorphous silicon, silicon nitride, silicon oxide and oxynitride films. The invention, however, may be used with any commercially available deposition system.

Referring to Fig. 1, the PECVD system modified in accordance with invention includes a deposition chamber 10 inside of which is a gas inlet manifold (or shower head) 12 for introducing deposition gases and a susceptor 14 for holding a substrate 16 onto which material is to be deposited. The inlet manifold 12 and the susceptor 14, which are both in the form of parallel plates, also function as upper and lower electrodes, respectively. The lower electrode and the chamber body are connected to ground. An RF generator 38 supplies RF power to the upper electrode through a matching network 40. The RF generator 38 is used to generate a plasma between the upper and lower electrodes.

The susceptor 14 includes a resistive heater 18 for heating the substrate during deposition. An external heater control module 20 powers the heaters to achieve and maintain the susceptor at an appropriate temperature level as dictated by the process being run in the system.

The susceptor is attached to the top of a movable shaft 22 that extends vertically through the bottom of the chamber. A motorized lift mechanism 24 moves the shaft in a vertical direction so as to raise the susceptor into position near the inlet manifold for a deposition run and to lower the susceptor after completing the deposition run. The separation between the upper and lower electrodes is adjustable to maximize reaction kinetics and film characteristics for the particular deposition process that is being performed. Below the susceptor there is a lift-off plate 26 with a set of vertical pins 28. The pins 28 are aligned with corresponding holes 30 in the susceptor 14. When the susceptor is lowered after a processing run, the pins pass through the holes, contact the back side of the substrate, and lift the substrate off of the susceptor so that it can be more easily removed from the chamber by a mechanical transfer mechanism (not shown).

Outside of chamber 10, there is a gas supply 32 containing the gases that are used during deposition. The particular gases that are used depend upon the materials are to be deposited onto the substrate. The process gases flow through an inlet port into the gas manifold and then into the chamber through the shower head. An electronically operated valve and flow control mechanism 34 controls the flow of gases from the gas supply into the

chamber. Also connected to the chamber through an outlet port is a vacuum pump 36, which is used to evacuate the chamber.

In accordance with the invention, a second gas supply system is also connected to the chamber through inlet port 33. The second gas supply system supplies gas that is used to clean the inside of the chamber after a sequence of deposition runs. By cleaning, we mean removing deposited material from the interior surfaces of the chamber.

The second gas supply system includes a source of a precursor gas 44, a remote activation chamber 46 which is located outside and at a distance from the deposition chamber, a power source 48 for activating the precursor gas within the remote activation chamber, an electronically operated valve and flow control mechanism 50, and a stainless steel conduit or pipe 57 connecting the remote chamber to the deposition chamber. The valve and flow control mechanism 50 delivers gas from the source of precursor gas 44 into the remote activation chamber 46 at a user-selected flow rate. The power source 48 activates the precursor gas to form a reactive species which is then flowed through the conduit 57 into the deposition chamber via inlet port 33. In other words, the upper electrode or shower head 12 is used to deliver the reactive gas into the deposition chamber. In the described embodiment, the remote chamber is a quartz tube and the power source is a 2.54 GHz microwave generator with its output aimed at the quartz tube.

Optionally, there may also be a source of a minor carrier gas 52 that is connected to the remote activation chamber through another valve and flow control mechanism 53. The minor carrier gas aids in the transport of the activated species to the deposition chamber. It can be any appropriate nonreactive gas that is compatible with the particular cleaning process with which it is being used. For example, the minor carrier gas may be argon, nitrogen, helium, hydrogen, or oxygen, etc. In addition to aiding in the transport of activated species to the deposition chamber, the carrier gas may also assist in the cleaning process or help initiate and/or stabilize the plasma in the deposition chamber.

In the described embodiment, there is a filter 56 in the conduit or pipe through which the activated species passes before entering the deposition chamber. The filter removes particulate matter that might have been formed during the activation of the reactive species. In the described embodiment, the filter is made of ceramic material having a pore size of about 0.01 to 0.03 microns. Of course, other materials can also be used, for example, teflon.

It should be noted that the filter can also be used to remove unwanted materials that might have been produced as byproducts of the reaction within the remote chamber. For example, if the reactive gas is  $CF_4$  or  $SF_6$  or some other halogen compound containing either carbon or sulfur, an activated carbon or sulfur species will be present as a byproduct of the activation process. It is

generally desired, however, that carbon and sulfur not be present in the deposition chamber. This is why these compounds are generally not used in conventional dry cleaning process where the activation occurs entirely within the deposition chamber. However, when the activation is performed remotely, as described herein, these materials can be easily removed by using an appropriate filter material. Such filter materials are readily available in the commercial market and are well known to persons of ordinary skill in the art.

In the described embodiment, the precursor is  $NF_3$ . The flow rate of activated species is about 2 liters per minute and the chamber pressure is about 0.5 Torr. To activate the precursor gas, the microwave source delivers about 500-1500 Watts to the activation chamber. Within the deposition chamber, the RF source supplies about 100-200 Watts to the plasma. For the AKT-1600 PECVD system this implies a voltage between the upper and lower electrodes of about 15-20 volts. Of course, the precise voltage and current are pressure dependent, i.e., the current is proportional to the pressure given a fixed voltage. In any event, it is only necessary to induce a gentle plasma within the chamber, which only need be strong enough to sustain the activated species that has been flowed into the chamber from the remote source.

By using  $NF_3$  as the feed gas, we have been able to clean chambers that have been deposited with silicon (Si), doped silicon, silicon nitride ( $Si_3N_4$ ) and silicon oxide ( $SiO_2$ ). The cleaning rate for as-deposited film has reached 2 micron/minute for silicon nitride and 1 micron/minute for silicon, doped silicon, and silicon oxide. These cleaning rates are two to four times faster than the conventional cleaning process which employs only a local plasma with a power level of about 2 kilowatts at 13.56 MHz RF.

Though a microwave generator was used in the described embodiment to activate the precursor gas, any power source that is capable of activating the precursor gas can be used. For example, both the remote and local plasmas can employ DC, radio frequency (RF), and microwave (MW) based discharge techniques. In addition, if an RF power source is used, it can be either capacitively or inductively coupled to the inside of the chamber. The activation can also be performed by a thermally based, gas break-down technique; a high intensity light source; or an X-ray source, to name just a few.

In general, the reactive gases may be selected from a wide range of options, including the commonly used halogens and halogen compounds. For example, the reactive gas may be chlorine, fluorine or compounds thereof, e.g.  $NF_3$ ,  $CF_4$ ,  $SF_6$ ,  $C_2F_6$ ,  $CCl_4$ ,  $C_2Cl_6$ . Of course, the particular gas that is used depends on the deposited material which is being removed. For example, in a tungsten deposition system a fluorine compound gas is typically used to etch and/or remove clean the deposited tungsten.

Because of the use of a local plasma in conjunction with the remote plasma, the remote activation chamber

can be placed farther away from the chamber. Thus, only tubing is needed to connect the two remote source to the local source. Some quenching of the activated species (i.e., deactivation of the activated species) may occur during the transfer. However, the local source compensates for any such quenching that may occur. In fact, some long lived activated species (e.g.  $F^*$ ) typically do not return to the ground state when quenched but rather they transition to an intermediate state. Thus, the amount of energy that is required to reactivate the quenched species is much less than is required to activate the gas in the remote activation chamber. Consequently, the local activation source (e.g. plasma) need not be a high energy source.

It should also be noted that by placing the remote source at a distance from the deposition chamber, the short lived radicals that are produced during the activation process will be quenched more completely than the long lived radicals as both are transferred to the deposition chamber. Thus, the reactive gas that flows into the deposition chamber will contain primarily the long lived radicals that have survived the transfer. For example, if  $NF_3$  is the reactive gas, two radicals are produced in the remote activation chamber, namely,  $N^*$  and  $F^*$ . The nitrogen radical is short lived and the fluorine radical is long lived. The nitrogen radical will typically not survive a long transfer from the remote chamber to the deposition chamber; whereas, a large percentage of the fluorine radicals will survive. This is a form of natural filtering that occurs in the system that may be very desirable. In the case of nitrogen radicals, for example, it is sometimes preferable that they not be present in the deposition chamber because their presence may result in the formation of  $N_xH_yF_z$  compounds, which, as previously described, can harm the pump. When the activation is performed in the deposition chamber, however, as in the case of conventional cleaning techniques, there is no easy way to eliminate the nitrogen radicals that are produced.

In the dry cleaning process, chamber pressure can be selected to lie anywhere within a fairly broad range of values without significantly affecting performance. The preferred pressure range is from about 0.1 to about 2 Torr, although pressures outside of that range can also be used. In addition, the frequencies that were chosen for the described embodiment were merely illustrative and the frequencies that may be used in the invention are not restricted to those used in the described embodiment. For example, with regard to the RF power source, any of a wide range of frequencies (e.g. 400 kHz to 13.56 MHz) are typically used to generate plasmas and those frequencies may also be used in the invention. In general, however, it should be understood that the power levels, flow rates, and pressures that are chosen are system specific and thus they will need to be optimized for the particular system in which the process is being run. Making the appropriate adjustments in process conditions to achieve optimum of performance for a particular system

is well within the capabilities of a person of ordinary skill in the art.

Although the described embodiment involved a PECVD system, the invention has far wider applicability. For example, the concept of a remote activation source (i.e., outside the main vacuum chamber), possibly used in conjunction with a local activation source (i.e., inside the main vacuum chamber) can be used in systems designed for any of the following purposes: PVD, CVD, ion doping, photoresist stripping, substrate cleaning, plasma etching.

Other embodiments are within the following claims.

#### Claims

1. A method for cleaning a deposition chamber that is used in fabricating electronic devices, said method comprising:
  - delivering a precursor gas into a remote chamber that is outside of the deposition chamber;
  - activating the precursor gas in the remote chamber to form a reactive species;
  - flowing the reactive species from the remote chamber into the deposition chamber; and
  - using the reactive species that is flowed into the deposition chamber from the remote chamber to clean the inside of the deposition chamber.
2. The method of claim 1 wherein the step of activating the precursor gas is performed by using a remote energy source.
3. The method of claim 1 further comprising using a local energy source to further excite the reactive species that has been flowed into the deposition chamber from the remote chamber.
4. The method of claim 3 wherein the precursor gas is selected from the group of gases consisting of all halogens and gaseous compounds thereof.
5. The method of claim 4 wherein the precursor gas is selected from the group of gases consisting of chlorine, fluorine, and gaseous compounds thereof.
6. The method of claim 2 wherein the remote energy source is a microwave energy source.
7. The method of claim 6 wherein the precursor gas is selected from the group of gases consisting of all halogens and gaseous compounds thereof.
8. The method of claim 7 wherein the precursor gas is selected from the group of gases consisting of chlorine, fluorine, and compounds thereof.
9. The method of claim 2 wherein the local energy

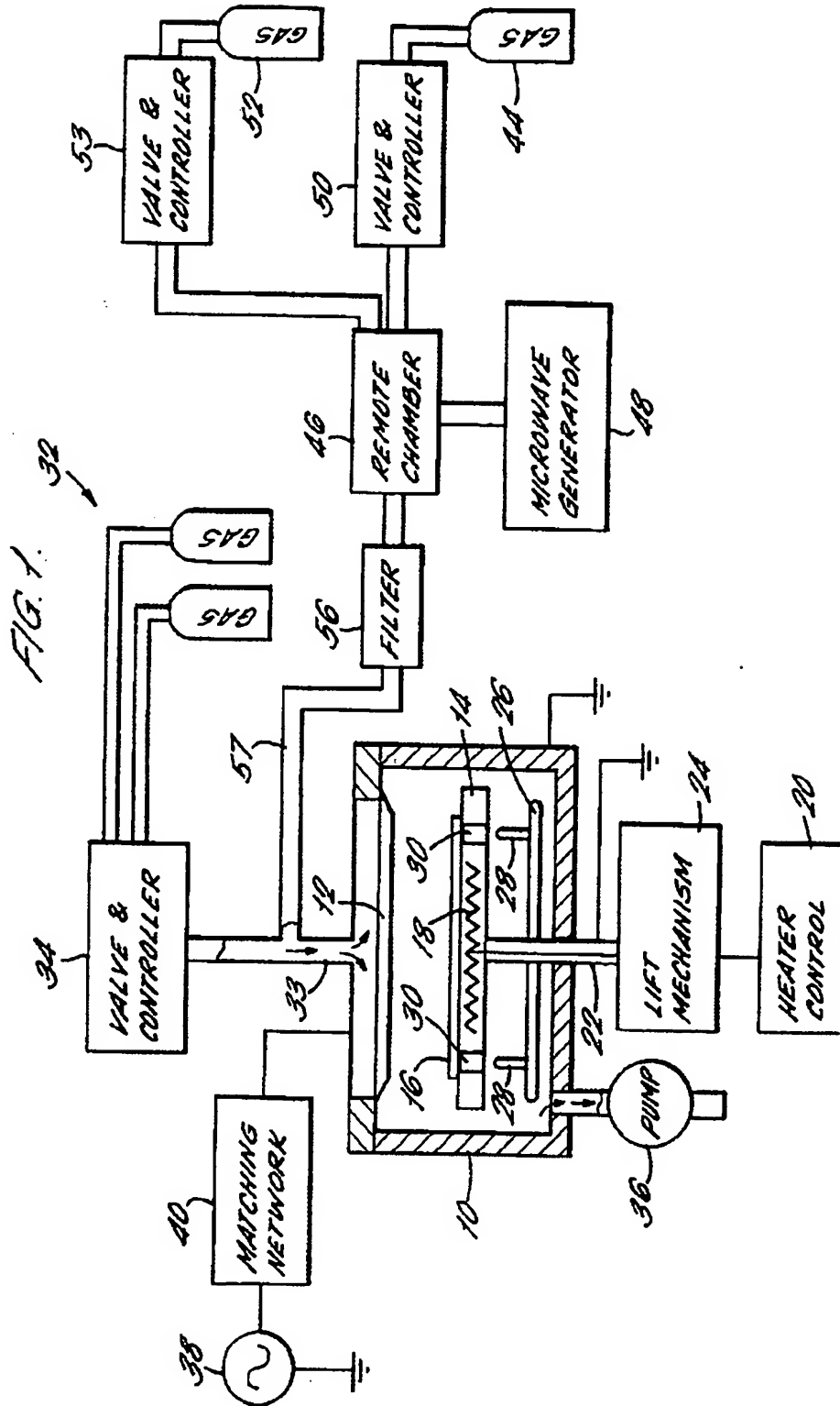


source is an RF energy source for generating a plasma within the deposition chamber.

10. The method of claim 2 further comprising filtering the reactive species before it enters the deposition chamber to remove unwanted materials. 5
11. The method of claim 2 further comprising flowing a carrier gas into the remote activation chamber. 10
12. The method of claim 11 wherein the carrier gas is selected from the group of gases consisting of nitrogen, argon, helium, hydrogen, and oxygen. 15
13. A method of performing a process to fabricate electronic devices within a process chamber, said method comprising:
  - delivering a precursor gas into a remote chamber that is outside of the process chamber;
  - activating the precursor gas in the remote chamber and to thereby form a reactive species;
  - flowing the reactive species from the remote chamber into the process chamber;
  - using a local activation source to further excite the reactive species that has been flowed into the process chamber from the remote chamber; and 20
  - using the reactive species that has been further excited by the local activation source in performing the fabrication process in the process chamber. 25
14. The method of claim 13 wherein the step of activating the precursor gas is performed by using a remote energy source. 30
15. The method of claim 13 wherein the precursor gas is selected from a group of gases consisting of halogen gases and compounds thereof. 35
16. The method of claim 15 wherein the precursor gas is selected from a group of gases consisting of chlorine, fluorine, and compounds thereof. 40
17. The method of claim 14 wherein the remote energy source is a microwave energy source. 45
18. The method of claim 17 wherein the precursor gas is selected from a group of gases consisting of halogen gases and compounds thereof.
19. The method of claim 18 wherein the precursor gas is selected from a group of gases consisting of chlorine, fluorine, and compounds thereof. 50
20. The method of claim 13 wherein the local energy source is an RF energy source for generating a plasma within the process chamber. 55
21. The method of claim 13 further comprising filtering

the reactive species before it enters the deposition chamber to remove unwanted materials.

22. The method of claim 13 further comprising flowing a carrier gas into the remote activation chamber.
23. The method of claim 22 wherein the carrier gas is selected from a group of gases consisting of nitrogen, argon, helium, hydrogen, and oxygen.
24. A deposition apparatus that can be connected to a source of precursor gas for cleaning, said apparatus comprising:
  - a deposition chamber;
  - a first activation source adapted to deliver energy into said deposition chamber;
  - a remote chamber that is outside of said deposition chamber;
  - a second activation source separate from said first activation source and adapted to deliver energy into said remote chamber;
  - a first conduit for flowing a precursor gas from a remote gas supply into the remote chamber where it is activated by said second activation source to form a reactive species; and
  - a second conduit for flowing the reactive species from the remote chamber into the deposition chamber.
25. The apparatus of claim 24 further comprising a valve and flow control mechanism which controls the flow of precursor gas into the remote chamber.
26. The apparatus of claim 25 further comprising a valve and flow control mechanism which controls the flow of a carrier gas that is different from the precursor gas into the remote chamber.
27. The deposition apparatus of claim 25 further comprising a filter in the second conduit to remove unwanted materials out of the flow of reactive species from the remote chamber.



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 95 30 4784

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cls)
X	US-A-5 328 558 (KAWAMURA KOUHEI) 12 July 1994	13-20, 22-26	C23C16/44 H01J37/32
Y	* column 3, line 18 - column 4, line 2; claim 1 *	21,27	
A	* column 5, line 58 - column 6, line 68 *	1-9,11, 12	
X	DE-A-41 32 559 (SIEMENS AG) 8 April 1993	1-9,11, 12,24-26	
Y	* claims 1,2 *	10,27	
A		13-23	
Y	PROCEEDINGS OF THE FIRST INTERNATIONAL SYMPOSIUM ON ULTRA LARGE INTEGRATION SCIENCE AND TECHNOLOGY/1987, PHILADELPHIA, PA, USA, 11-15 MAY 1987, 1987, PENNINGTON, NJ, USA, ELECTROCHEM. SOC, USA, pages 805-821, OHMI T ET AL 'Ultra clean gas delivery system for ULSI fabrication and its evaluation' * page 808, line 1 - line 16 *	10,21,27	TECHNICAL FIELDS SEARCHED (Int.Cl.6) C23C
X	EP-A-0 555 546 (IBM) 18 August 1993 * column 4, line 37 - column 5, line 1 *	1,2,6-8	
X	PATENT ABSTRACTS OF JAPAN vol. 005 no. 015 (E-043), 29 January 1981 & JP-A-55 145338 (TOSHIBA CORP) 12 November 1980, * abstract *	1,2,6-8	
X	US-A-4 867 841 (LOEWENSTEIN LEE M ET AL) 19 September 1989 * claim 1 *	13-20, 22,23	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 20 October 1995	Examiner Ekhlut, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1500 (01.93) (P0601)

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Satoh et al.
Appl. No.	:	10/759,953
Filed	:	January 16, 2004
For	:	SEMICONDUCTOR- PROCESSING DEVICE PROVIDED WITH A REMOTE PLASMA SOURCE FOR SELF- CLEANING
Examiner	:	Lund, Jeffrie Robert
Group Art Unit	:	1763

DECLARATION OF KIYOSHI SATOH UNDER 37 C.F.R. § 1.132**Mail Stop AF**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

I, Kiyoshi Satoh, do hereby declare and say as follows:

1. I am currently employed as a manager of a technical support group in the department of Customer Service at ASM Japan K.K. I joined ASM Japan K.K. in 1991 as a member of the Research and Development group. Over the last 16 years, I have worked in various capacities as a research and development engineer, project manager, and most recently as a manager of the technical support group in the customer service department. In particular, my work has focused on the development of plasma CVD deposition processes and apparatus. I am an inventor on various patents in the field of semiconductor fabrication, including the following U.S. patents: 6,193,803, 6,120,605, 6,767,836, 6,235,112, 6,113,704, 6,435,798, 6,736,147, 6,761,771, 6,919,270, 6,991,959, and 6,815,332. I am also listed as an inventor on the present patent Application. Prior to my work in the semiconductor industry, I earned a bachelor's degree in chemistry at Kumamoto University.

Appl. No. : 10/759,953  
Filed : January 16, 2004

2. I have read and understand the claims in the present patent application. I understand that the claims concern a CVD device involving a deposition reaction chamber, a plasma discharge chamber that is remote from the reaction chamber, a piping between the two, and a valve in the piping, as well as other elements. Additionally, the valve, when fully opened, allows for a pressure drop across the valve of less than about 0.25 Torr, has a valve opening that is substantially as wide as the inner surface of the piping, and/or has a valve body that does not have projections with respect to the inner surface of the piping.

3. I have read and understand the rejections in the Final Office Action dated November 16, 2006. I understand that the Examiner has asserted that U.S. Pat. Nos. 5,812,403 and 5,939,831 to Fong et al. teach a valve that, when fully opened, has an opening that is sized substantially equal in width to the inner surface of the piping and does not have projections with respect to the inner surface of the piping. In particular, the Examiner's cited support for such a teaching is allegedly found in Figures 3 and 6a of each of the Fong et al. patents.

4. After having read both U.S. Pat. Nos. 5,812,403 and 5,939,831, it is my considered opinion that these patents do not teach the relevant valve, as presently claimed and described above in paragraph 2. I understand the cited sections in Fong et al. (Figures 3 and 6a) to merely demonstrate a schematic of the concept of a gate valve and not the particularly recited valve. Figure 3 merely represents the valve as a block 280 with a fluid passage 293 passing through it. There is no disclosure of the actual valve body or how it is involved. Thus, there is no disclosure regarding the possible position of the valve body when the valve is fully opened. Figure 6a represents the valve 280 as a block with a passageway. There is no depiction of the actual valve body. Thus, while Figures 3 and 6a do depict a valve 280 in a passageway, there is no actual teaching that the valve is configured so that, when fully opened, the opening through the valve is substantially equal in width to an inner surface of the piping and/or the valve does not have projections with respect to the inner surface of the piping.

5. There is nothing in the detailed descriptions of the two Fong et al. patents that alters my above analysis of Figures 3 and 6a. Thus, the Fong et al. patents do not teach a valve with the recited characteristics of a particular maximum pressure drop or a valve body that does not have projections with respect to the inner surface of the piping.

6. It is my opinion that one of skill in the art, after reviewing the Fong et al. patents, would conclude that, in some embodiments of the disclosed device in Fong et al. a valve can be

Appl. No. : 10/759,953  
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used. However, they would not conclude that Fong et al. teaches or suggests a valve with the characteristics described in paragraph 2 of this Declaration.

7. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. I declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

Dated: Jan. 05, 2007

By: K Satoh  
Kiyoshi Satoh

3215641  
121506

Docket No. : ASMJP.055DV1

**Customer No.: 20,995**

Application No. : 10/759,953

Filing Date : January 16, 2004

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**APPENDIX C  
RELATED PROCEEDINGS APPENDIX**

No related appeal proceedings are known.